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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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L. C. EVANS,
Town Clerk. D 757

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THE SECRETARY OF STATE FOR INDIA IN COUNCIL is prepared to receive

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20th February, 1920. D 705

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Applications are Invited for the POST of HEAD of the ENGINEERING DEPARTMENT, County Technical College, Wednesbury, at a salary of £600.

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GRAHAM BALFOUR,
Director of Education.
County Education Offices,
Stafford.
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H. SCHOFIELD, M.B.E., B.Sc., A.R.C.Sc., A.M.I.C.E., Principal.

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THE SECRETARY OF THE ADMIRALTY,
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Candidates will be required to take day and evening classes in Mechanical Engineering, including Laboratory Work. They should possess a university degree or its equivalent, and have had workshop experience. Previous teaching experience and laboratory practice essential.

Commencing salary £250 to £350, according to experience and qualifications. A scale of salaries is at present under consideration.

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Education Offices,
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Bolton. D 544

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Four Assistant Engineers REQUIRED for the Government Railway Open Lines Department, FEDERATED MALAY STATES, for three years' service with possible permanency. Salary 400 dollars a month, rising by annual increments of 25 dollars a month to 500 dollars a month. (The sterling value of the dollar is at present fixed by the Government at 2s. 4d.) Free passages. Candidates must be under 35 and preferably single, and must be qualified Civil Engineers with experience of railway maintenance. They must also be capable of setting out and supervising the construction of new works.—Apply within one week from date of this advertisement, by letter, giving brief details of age and experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting M./F.M.S. 9520. D 760

THE THEORY OF THE MICHELL THRUST BEARING.

In view of the fact that the Michell type of thrust block has been definitely adopted as the Navy standard and is becoming increasingly popular in the merchant service, a somewhat detailed discussion of the mathematical theory of the device may be of interest, the more so in that Mr. Anthony G. M. Michell in developing this theory made the only really important extension to Osborne Reynold's theory of lubrication yet effected. His account of the theory appeared in the *Zeitschrift für Mathematik und Physik* in 1905, and thus, although written in English, is not readily accessible to British engineers.

The "qualitative" theory of the block is now pretty well known, but as it will serve as a starting point for the "quantitative" discussion of the problem presented it may be worth while to recall it here.

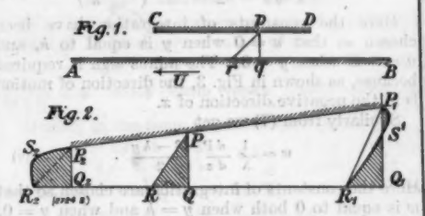
Suppose, for instance, that we have two parallel surfaces as represented in Fig. 1 by C D and A B, and that the latter is sliding under the former in the direction indicated by the arrow. If a film of lubricant be introduced between the two surfaces it will adhere to both and be subjected to a shearing action. The velocity of the fluid at any point will then be represented by the triangle $r\,p\,q$, being equal to $r\,q$ at the surface A B and to zero at the upper surface C D. If a load be applied to the upper plate the lubricant will simply be squeezed out and the two solid surfaces will finally come into physical contact.

If, however, the upper surface instead of being parallel to the lower is inclined to it, as indicated in Fig. 2, the film can sustain a pressure and the block carry a load. This follows because (assuming leakage to be prevented at the sides of the block) as much lubricant must enter across the line P_1Q_1 as leaves across the line P_2Q_2. Hence the mean velocity at the trailing edge of the block must be higher than the mean velocity at the leading edge, since P_1Q_1 is greater than P_2Q_2. The curve of velocities at these two sections can therefore no longer be represented as a straight line, but has forms somewhat of the character represented by the curves $P_1S_1R_1$ and $P_2S_2R_2$ respectively. This bulging of the velocity curves can only be produced by an hydraulic pressure within the film, and this pressure acting equally in all direction tends to force the two opposing surfaces apart and enables them to sustain a load without coming into physical contact. In short, the moving surface $R_1\,R_2$ drags in oil and crowds it into a continuously narrowing space. As the oil is almost incompressible, the surplus has to escape and must do so either at the sides or at the leading edge of the block as indicated by the negative loop of the velocity curve between P_1 and S. For the case in which side leakage is prevented Osborne Reynolds worked out the relationship between the load sustained, the viscosity of the oil, the relative speed of the moving surfaces and the thickness of the oil film. A full and detailed discussion of the theory of lubrication so far as Osborne Reynolds carried it has already appeared in our columns* in the autumn of 1915. In all the cases discussed by him, however, the fact that oil escapes at the sides of the brass was neglected, and the conclusions reached were perhaps a little liable to convey a false impression as to what occurred in bearings of finite dimensions.

Taking the case of a block of length a measured in the direction of motion and of unlimited width transverse to this direction, he showed that the total load supported per cm. run (*not* per square cm.) was given by the relation

$$\dagger W = \frac{\lambda U . a^2}{h_0^2} . \phi \quad . \quad . \quad . \quad . \quad (1)$$

where W denotes the load in dynes per centimetre run (measured transverse to the direction of motion) λ is the viscosity of the oil in dynes per square centimetre. U is the relative velocity of the opposing surfaces in centimetres per second, whilst a as already stated, denotes the length of the block and h_0 is the thickness of the oil film at the trailing edge. ϕ is a coefficient which depends upon the angle between the opposing surfaces of the bearing, and, when this is such, that the film thickness at the leading edge is twice h_0, has the value 0·159 for the case studied by Osborne Reynolds. Reynolds showed in fact, that when this was the case the load carried was very nearly the maximum possible for a given value of h_0, and Mr. Michell in developing his extension of Reynolds' theory has assumed that



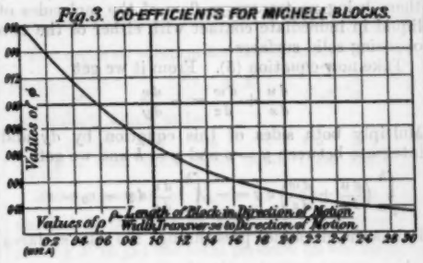
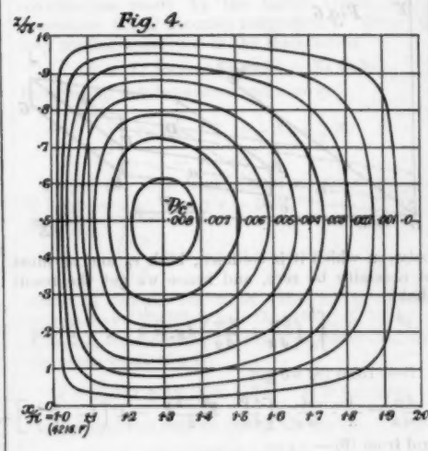
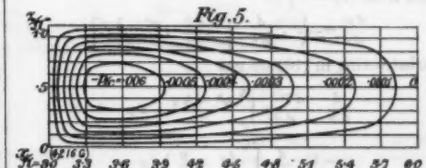


Fig.3. CO-EFFICIENTS FOR MICHELL BLOCKS.
Values of φ
Values of ρ
Length of Block in Direction of Motion
Width Transverse to Direction of Motion



this also holds true, when the width w of the block (taken transverse to the line of motion) is finite.

In essentials, the problem which Mr. Michell set himself and succeeded in solving was to determine what the value of the coefficient ϕ was for finite values of w. The mathematical theory is much more complex than it was in the case discussed by Reynolds, but the principal results can be represented by a curve as in Fig. 3. This has been plotted from five points, of which the initial point for $\frac{w}{a} = \infty$ is given by Reynolds' theory. Two points, for values of $\frac{w}{a} = 1$ and $\frac{w}{a} = 3$, have been plotted from Mr. Michell's calculations, whilst two other points represent the results of a calculation made by the present writer as it seemed desirable to determine the shape of the curve in the immediate neighbourhood of Reynolds' limiting case.

It may be convenient to give some general discussion of formula (1) and the curve figure 3 before entering into the somewhat complicated mathematical processes by which the values of ϕ used in plotting the curve were determined.

From formula (1) it is evident that for geometrically similar conditions and for given values of λ and U, the load carried per centimetre of transverse length is constant. Thus, for a block of given shape the load carried per unit of transverse length is the same whatever the dimensions of the block. If of two similar blocks the one measures 5 centimetres in transverse length and another 10, and the oil films are also geometrically similar, then for given values of λ and U each will carry the same load per centimetre run. Hence the total load carried by the smaller block will be one-half the total load carried by the other. At the same time its factor of safety will be less and for two reasons. In the first place, with similar geometrical conditions, the film thickness will be only half as great as with the larger block, and secondly the work expended in friction per centimetre of transverse length will be identically the same in the two cases, but with the smaller block the heat generated will be absorbed by one-half the amount of oil. Hence to preserve the same average temperature and viscosity in the film of oil this must be supplied to the smaller block at a lower initial temperature. Again, if the thickness of the film is the measure of safety, then for the same factor of safety the smaller block must only be loaded one-quarter as heavily per centimetre run as the larger block. It is doubtful, however, if the thickness of the film can be regarded as the sole criterion of the factor of safety.

In general, the problem that may arise in practice is to find the best ratio of a (the length of the block in the direction of motion) to w the transverse width, which is commonly more or less fixed by practical considerations. This problem can be solved at least roughly by the aid of Fig. 3.

Let us assume as a first approximation that two blocks of length $\frac{a}{2}$ can be accommodated in the same space as one block of length a, the width w being the same for both cases. Consider the three cases of $a = \frac{1}{2}w$, $a = w$ and $a = 2w$. Then taking the corresponding values of ϕ from the curve, Fig. 3, and assuming that h_0 is to be same in all cases, we have:—

$$W_{\frac{1}{2}} = \frac{\lambda U w^2}{4 h_0^2} \phi_{\frac{1}{2}} = \frac{\lambda U w^2}{h_0^2}\left[\frac{0{\cdot}116}{4}\right]$$

$$W_1 = \frac{\lambda U w^2}{h_0^2} \phi_1 = \frac{\lambda U w^2}{h_0^2} \quad [{\cdot}0669]$$

$$W^2 = \frac{\lambda U 4w^2}{h_0^2} \phi_2 = \frac{\lambda U w^2}{h_0^2} \quad (4 \times 0.030)$$

On the assumption made we can get four blocks of width $\frac{1}{2}w$ in the same space as one block of width $2w$, the relative loads carried with a constant value of h_0 will be in the ratios of the numbers ·116, 0·1338 and ·120.

The narrow block is, therefore, the least economical of the three. The advantage thus lies with the square block, though this will be reduced if, as there seems some reason for believing, a lesser value of h_0 is practicable with small than with large blocks. On the other hand, narrow blocks imply the use of a correspondingly greater number of parts, which is likely to increase manufacturing costs. It may be observed, however, that with these narrow blocks it is possible to approach more nearly to the conditions assumed in the mathematical theory than with broader blocks. The blocks have, in fact, to be sector-shaped, whereas in the calculation they are assumed to be rectangular, and the narrow block departs less from this form than does a broader one.

On the assumptions made the heat generated would be the same in all three cases. In practice, however, it would probably prove rather less with the more numerous blocks, thus increasing the total load carried for a given value of h_0.

From his calculations Mr. Michell has plotted the curves in Fig. 4, showing the distribution of pressure over a square block; whilst a similar set of curves, also due to him and reproduced in Fig. 5, show the lines of equal pressure in a block with $a = 3w$. In the case of the square block, it appears, taking Mr. Michell's figures as a basis for calculation, that

* See ENGINEERING, vol. c (July to December, 1915), pages 101, 154, 196 and 207.

† There is a misprint in Osborne Reynolds' paper, where a^3 has been substituted for a^2. Scientific Papers, vol. ii, page 265.

⅓ of the oil escapes at the sides of the block and under the trailing end.

The curve for ϕ, Fig. 3, has been plotted from the values given in the table below. The last column of this table shows the distance of the centre of pressure from the trailing edge of the block expressed as a fraction of the total length of the block measured in the direction of motion. These values have been obtained by approximate methods of integration, and different formulas have been employed in different cases, and there is thus a slight discrepancy. This, however, is not a matter of much importance, since, owing to the fact that the viscosity of the oil diminishes as it heats up during its passage under the block, the position of the centre of pressure tends to shift forward in advance of the position it would occupy did the viscosity remain unaltered. It is this fact that makes it possible to use centrally-pivotted blocks, as was first pointed out by Mr. H. T. Newbigin:—

$\frac{\text{Length of Block}}{\text{Width of Block}} = \frac{a}{w}$.	ϕ	Distance of Centre of Pressure from Trailing End of Block.
0	·159	·450
$\frac{1}{\pi}$	·139	·431
$\frac{1}{\pi}$	·127	·433
1	·0687	·420
3	·0146	·390

Following Osborne Reynolds, Mr. Michell, in developing his theory, starts with the four partial differential equations which represent the flow of an incompressible viscous fluid under pressure. A method of establishing these equations from first principles was set out in full detail in our issue of July 30, 1915, so that it will be unnecessary to do more than quote them here, viz.:—

$$\frac{dP}{dx} = \lambda\left(\frac{d^2u}{dx^2} + \frac{d^2u}{dy^2} + \frac{d^2u}{dz^2}\right). \quad . \quad (2)$$

$$\frac{dP}{dy} = \lambda\left(\frac{d^2v}{dx^2} + \frac{d^2v}{dy^2} + \frac{d^2v}{dz^2}\right). \quad . \quad (3)$$

$$\frac{dP}{dz} = \lambda\left(\frac{d^2w}{dx^2} + \frac{d^2w}{dy^2} + \frac{d^2w}{dz^2}\right). \quad . \quad (4)$$

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = 0 \quad . \quad . \quad . \quad (5)$$

In these equations P denotes the pressure (in dynes per square centimetre)* at any point of the liquid, λ its viscosity in dynes per square centimetre, whilst u, v, and w are the components of the velocity of flow parallel to the axes of X, Y, and Z. This velocity is measured in centimetres per second.

To apply these equations to the problem of the Michell block, we shall refer the block to rectangular axes taken as in Fig. 6. Here the lower face of the block is represented by A B G D, and makes an angle c with the plane Z O X, which is assumed to be continually moving under the block with a velocity equal to U and in the direction indicated by the arrow. The side E B of the block is taken to lie in the vertical plane Y O X, and the axis of Z is the line in which the plane A B G D produced cuts the horizontal plane X O Z.

The film thickness being extremely small, the pressure in the fluid at any point of the underface of the block must be sensibly the same as the pressure at a point of the moving plane vertically below it. In other words, the pressure at any point in the film does not vary throughout the thickness of this film—that is to say, with the height y above the plane Z O X. Hence in equation (3) we can write $\frac{dP}{dy} = 0$, so that P is not a function of y.

Next consider the velocity of flow at any point of the fluid film. When $y = 0$ this velocity is equal to U, whilst it is zero when y is equal to h, where h represents the height of any point of the underface of the block above the plane Z O X. As the film is very thin it will be seen that the velocity varies very rapidly with y, so that $\frac{du}{dy}$ is very large compared with either $\frac{du}{dx}$ or $\frac{du}{dz}$

* A million dynes per square centimetre represents a pressure of about one atmosphere.

Hence we shall make no serious error if we write equations (2) and (4), as—

$$\frac{dP}{dx} = \lambda\frac{d^2u}{dy^2} \quad . \quad . \quad . \quad . \quad (6)$$

$$\frac{dP}{dz} = \lambda\frac{d^2w}{dy^2} \quad . \quad . \quad . \quad (7)$$

Now since P is not a function of y, both these equations can be integrated directly.

From (6) we get—

$$u = \frac{1}{\lambda}\frac{dP}{dx}\frac{y^2 - hy}{2} - U\left(1 - \frac{y}{h}\right) \quad . \quad (8)$$

Here the constants of integration have been chosen so that $u = 0$ when y is equal to h, and $u = -U$ when $y = 0$. The minus sign is required because, as shown in Fig. 3, the direction of motion is in the negative direction of x.

Similarly from (7) we get

$$w = \frac{1}{\lambda}\frac{dP}{dz}\frac{y^2 - hy}{2} \quad . \quad . \quad . \quad (9)$$

Here the constants of integration are chosen so that w is equal to 0 both when $y = h$ and when $y = 0$, there being no transverse flow of the molecules of liquid in immediate contact with either of the two opposing solid surfaces.

Take now equation (5). From it we get

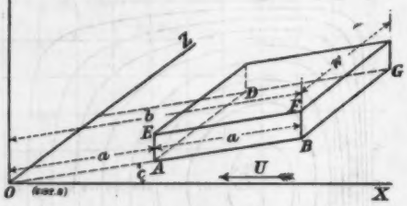
$$\frac{du}{dx} + \frac{dw}{dz} = -\frac{dv}{dy}$$

Multiply both sides of this equation by dy and integrate between $y = o$ and $y = h$ and we get

$$\int_o^h\left(\frac{du}{dx} + \frac{dw}{dz}\right)dy = -\int_o^h\frac{dv}{dy}dy = v_0 - v_h$$

But as the oil cannot pass through the solid surfaces

Fig. 6.



between which it is confined, both v_0 and v_h must of necessity be zero, and hence we get the result that

$$\int_o^h\left(\frac{du}{dx} + \frac{dw}{dy}\right)dy = 0 \quad . \quad . \quad (10)$$

Now from (8) we get

$$\frac{du}{dx} = \frac{1}{\lambda}\cdot\frac{d}{dx}\cdot\left[\frac{dP}{dx}\cdot\frac{y^2 - hy}{2} - U\left(1 - \frac{y}{h}\right)\right]$$

and from (9)—

$$\frac{dw}{dz} = \frac{1}{\lambda}\cdot\frac{d}{dz}\cdot\left[\frac{dP}{dz}\cdot\frac{y^2 - hy}{2}\right]$$

Substituting in (10) we get

$$\frac{d}{dx}\cdot\frac{dP}{dx}\cdot\int_o^h\frac{y^2 - hy}{2\lambda}\cdot dy$$

$$- U\cdot\frac{d}{dx}\int_o^h\left(1 - \frac{y}{h}\right)dy$$

$$+\frac{d}{dz}\cdot\frac{dP}{dz}\cdot\int_o^h\frac{y^2 - hy}{2\lambda}\cdot dy = 0 \quad . \quad (11)$$

Now

$$\int_o^h\frac{y^2 - hy}{2}dy = \frac{y^3}{6}\Big]_o^h - \frac{hy^2}{4}\Big]_o^h = -\frac{h^3}{12}$$

and

$$\int_o^h\left(1 - \frac{y}{h}\right)dy = y\Big]_o^h - \frac{y^2}{2h}\Big]_o^h = \frac{h}{2}$$

Hence (11) reduces to

$$\frac{d}{dx}\cdot\frac{dP}{dx}\cdot h^3 + \frac{d}{dz}\cdot\frac{dP}{dz}\cdot h^3 = -6\lambda U\frac{dh}{dx}$$

But from Fig. 6, $h = cx$ (c being a very small angle), and substituting this, and neglecting (for convenience) the negative sign on the right, we get the partial differential equation

$$\frac{d}{dx}\cdot x^3\frac{dP}{dx} + x^3\frac{d^2P}{dz^2} = \frac{6\lambda U}{c^3}$$

which may be written in the form

$$\frac{d^2P}{dx^2} + \frac{3}{x}\frac{dP}{dx} + \frac{d^2P}{dz^2} = \frac{6\lambda U}{c^3x^3} \quad . \quad (12)$$

To any such partial differential equation there are an infinite number of solutions, and the problem is to select from this infinite variety those which, either singly or added together, satisfy the special physical conditions of the particular problem in hand. In the present case we know that the pressure in the oil film is zero at each of the four edges of the block.

There is only one solution of equation (12) or one set of solutions added together which will satisfy this physical condition.

The general method of solving such an equation is to assume that P can be expressed in the form $P = X_0Z_0 + X_1Z_1 + \&c.$, where X denotes a function of x only and Z a function of z only. Both sides of the equation must be written in this form, and then the values of X_0, X_1, X_2, &c., are separately determined.

Let us assume that the width of the block measured parallel to the Z axis is π, and that

$$P = X\sin z + X_3\sin 3z + X_5\sin 5z + \&c.$$

Then when $z = 0$, P is equal to 0, and when $z = \pi$ (which is the width of the block), P is again equal to 0, so that two of the physical conditions of the problem will be satisfied if the assumption made proves workable.

Adopting it, the left-hand side of equation (12) becomes the sum of a number of terms such as

$$\sin nz\frac{d^2X_n}{dx^2} + \sin nz\frac{3}{x}\cdot\frac{dX_n}{dx} - \sin nz\,n^2X_n$$

It is next necessary to express the right-hand side of equation in a similar form. This can be done by making use of the well-known Fourier expansion, viz.:—

$$\frac{\pi}{4} = \sin z + \frac{\sin 3z}{3} + \frac{\sin 5z}{5} + \&c.$$

which is valid between the limits 0 and π.

Employing this proposition we find that

$$\frac{6\lambda U}{c^3x^3} = \frac{6\lambda U}{c^3x^3}\frac{4}{\pi}\cdot\left(\sin z + \frac{\sin 3z}{3} + \sin\frac{5z}{5} + \&c.\right)$$

Hence equation (12) becomes the sum of the series of equations

$$\sin z\left[\frac{d^2X_1}{dx^2} + \frac{3}{x}\frac{dX_1}{dx} - X_1\right] = \frac{6\lambda U}{c^3x^3}\frac{4}{\pi}\cdot\sin z$$

$$\sin 3z\left[\frac{d^2X_3}{dx^2} + \frac{3}{x}\frac{dX_3}{dx} - 9X_3\right] = \frac{6\lambda U}{c^3x^3}\frac{4}{\pi}\cdot\frac{\sin 3z}{3}$$

$$\sin 5z\left[\frac{d^2X_5}{dx^2} + \frac{3}{x}\frac{dX_5}{dx} - 25X_5\right] = \frac{6\lambda U}{c^3x^3}\frac{4}{\pi}\cdot\frac{\sin 5z}{5}$$

and so on.

The general term is thus

$$\sin nz\left[\frac{d^2X_n}{dx^2} + \frac{3}{x}\frac{dX_n}{dx} - n^2X_n\right] = \frac{24\lambda U}{c^3\pi x^3}\cdot\frac{\sin nz}{n}$$

where n is an odd integer.

Dividing both sides by $\sin nz$, we get

$$\frac{d^2X_n}{dx^2} + \frac{3}{x}\frac{dX_n}{dx} - n^2X_n = \frac{24\lambda U}{nc^3\pi x^3}$$

If we change the variable from x to r where $r = nx$, the equation takes the form

$$n^2\frac{d^2X_n}{dr^2} + \frac{3n^2}{r}\frac{dX_n}{dr} - n^2X_n = \frac{24n^2\lambda U}{c^3\pi r^3}$$

All the equations in X thus become identical in form with

$$\frac{d^2X}{dr^2} + \frac{3}{r}\cdot\frac{dX}{dr} - X_n = \frac{24\lambda U}{c^3\pi r^3} \quad . \quad (13)$$

and the solution of this one equation will be (formally) the solution of all.

If we write $X = \frac{V}{r}$, equation (13) is transformed to a form which has been very thoroughly studied. It becomes

$$\frac{d^2V}{dr^2} + \frac{1}{r}\cdot\frac{dV}{dr} - \left(1 + \frac{1}{r^2}\right)V = \frac{24\lambda U}{c^3\pi r^2}$$

For shortness let us put $\frac{24\lambda U}{c^3\pi} = k$, and the equation to be solved is then

$$\frac{d^2V}{dr^2} + \frac{1}{r}\cdot\frac{dV}{dr} - \left(1 + \frac{1}{r^2}\right)V = \frac{k}{r^2} \quad . \quad (14)$$

From the theory of differential equations it is known that the complete solution of this consists of three parts, viz., any one solution whatever of (14) plus any two independent solutions of the

equation

$$\frac{d^2V}{dr^2} + \frac{1}{r}\cdot\frac{dV}{dr} - \left(1+\frac{1}{r^2}\right)V = 0 \quad . \quad (15)$$

This latter is a Bessel equation, of which two independent solutions are known as $A\,I_1$ and $B\,K_1$, where A and B are constant coefficients which may have any value whatever, and can thus be chosen to fit the special physical conditions of any particular problem in hand.

I_1 can be expressed as the series

$$I_1 = \frac{r}{2} + \frac{r^3}{2^2.4} + \frac{r^5}{2^2.4^2.6} + \&c.$$

which, if substituted for V in equation (15), will be found to satisfy it. No similar simple expression can be found for K_1, but if we assume that $V = I_1 \log x + Q$, where Q is an unknown function, we can find a second independent solution.

Thus on differentiating we get

$$\frac{dV}{dr} = \frac{dI_1}{dr}\log x + \frac{I_1}{r} + \frac{dQ}{dr}$$

$$\frac{d^2V}{dr^2} = \frac{d^2I_1}{dr^2}\log x + \frac{2}{r}\cdot\frac{dI_1}{dr} - \frac{I_1}{r^2} + \frac{d^2Q}{dr^2}$$

Substituting these values in equation (15) we get

$$\left[\frac{d^2I_1}{dr^2} + \frac{1}{r}\cdot\frac{dI_1}{dr} - I_1\left(1+\frac{1}{r^2}\right)\right]\log x + \frac{2}{r}\cdot\frac{dI_1}{dr} = Q\left(1+\frac{1}{r^2}\right) - \frac{1}{r}\frac{dQ}{dr} - \frac{d^2Q}{dr^2}$$

But since I_1 is itself a solution of (15), the coefficient of $\log x$ is zero, and we have simply

$$Q\left(1+\frac{1}{r^2}\right) - \frac{1}{r}\cdot\frac{dQ}{dr} - \frac{d^2Q}{dr^2} = \frac{2}{r}\frac{dI}{dr} = \frac{1}{r} + \frac{6r}{2^2.4} + \frac{10r^3}{2^2.4^2.6} + \&c. \quad . \quad . \quad (16)$$

If we now assume that

$$Q = \frac{A}{r} + B\,r + C\,r^3 + D\,r^5 + \&c.$$

and substitute in (16), we find on comparing coefficients of the powers of r that

$$A = 1,\ B = 0,\ C = -\frac{6}{128}$$

$$D = -\frac{28}{9216} \qquad E = -\frac{70}{884{,}736}$$

and so on.

Both this series and that already given for I_1 converge rapidly for small values of r. It is, however, unnecessary to calculate I_1 for small values of r, as tables have been prepared by the British Association giving I_1 for values of r between the limits $r = o$ and $r = 6$.

For large values of r it has been proved that provided we stop at a term of small numerical value,

$$I_1 = \frac{e^r}{\sqrt{\pi r}}\left(1 - \frac{3}{8r} - \frac{3.5}{2}\cdot\left(\frac{1}{8r}\right)^2 - \frac{3.5.21}{2.3}\cdot\left(\frac{1}{8r}\right)^3 + \&c.\right]$$

and

$$K_1 = -\frac{e^{-r}}{\sqrt{\pi r}}\left(1 + \frac{3}{8r} - \frac{3.5}{2}\cdot\left(\frac{1}{8r}\right)^2 + \frac{3.5.21}{2.3}\cdot\left(\frac{1}{8r}\right)^3 + \&c.\right]$$

A series of this type is known as an asymptotic series. As additional terms are taken into account, the value obtained at first approaches to the true value of the function, and t en as still more terms are taken, diverges again from it.

We next require some "particular" solution of (14), let us therefore assume that

$$V = \alpha + \beta r^2 + \gamma r^3 + \&c.$$

and substitute this in the equation. Then by comparing the coefficients of the powers of r on the two sides of the equation we find that

$$V = k\cdot\left(1 + \frac{r^2}{3} + \frac{r^4}{3^2.5} + \frac{r^6}{3^2.5^2.7}\right) + \&c.$$

$$= L \text{ say}$$

Consider the case in which the block extends from $x = \cdot6$ cm. to $1\cdot2$ cm., the transverse width w being π cm. Then from the series given we get the following as the numerical values of I_1 K_1 and L_1 for different values of x—

x	I_1	K_1	L
·6	·31370	1·49606	1·12291
·7	·37186	1·27 85	1·16874
·8	·43286	1·12340	1·22260
·9	·49713	1·02273	1·2·492
1·0	·56516	·95002	1·35619
1·1	·63749	·90242	1·43701
1·2	·71468	·87429	1·52802

Then the general solution of the equation

$$\sin z\left[\frac{d^2X}{dz^2} + \frac{3}{z}\frac{dX}{dz} - X\right] = \frac{6\lambda U}{c^2 z^3}\cdot\frac{4}{\pi}\cdot\sin z$$

is $$Z_1X_1 = \frac{\sin z}{z}\left[A\,I_1 + B\,K_1 + L\right] \times \frac{6\lambda U}{c^2}\cdot\frac{4}{\pi}$$

To satisfy the physical conditions of the problem it is necessary that A and B shall be chosen, so that $X_1 = 0$, both when $x = 0.6$ and when $x = 1\cdot2$, that is to say, at the trailing and leading edges of the block. Hence

$$A = -1.6402 \text{ and } B = -0.40668.$$

Substituting these values we get the following values of X_1 for different values of x:

x =	0·6	0·7	0·8	0·9	1·0	1·1	1·2
$\frac{c^2\pi X_1}{24\lambda U}$ =	0	·05513	·06719	·05962	·04281	·02226	0

Dealing in the same way with the equation

$$\sin 3z\left[\frac{d^2X_3}{dz^2} + \frac{3}{z}\cdot\frac{dX_3}{dz} - 9X\right] = \frac{6\lambda U}{c^2 z^3}\cdot\frac{4}{\pi}\cdot\frac{\sin 3z}{3}$$

we get the following values for X_3:

x =	·6	·7	·8	·9	1·0	1·1	1·2
$\frac{c^2\pi X_3}{24\lambda U}$ =	·0000	·01505	·01778	·01583	·01126	·00597	·0000

The required solution for the equation

$$\sin 5z\left[\frac{d^2X_5}{dz^2} + \frac{3}{z}\cdot\frac{dX_5}{dz} - 25X\right] = \frac{6\lambda U}{c^2 z^3}\cdot\frac{4}{\pi}\cdot\frac{\sin 5}{5}$$

is similarly found to be

x =	·6	·7	·8	·9	1·0	1·1	1·2
$\frac{c^2\pi X_5}{24\lambda U}$ =	·0000	·00672	·00758	·00640	·00455	·00243	·0000

The mean value of $X_n \sin nz$ taken along a line parallel to the axis of z is $\frac{2}{n}\cdot X_n$, so that on integrating P to get the total pressure on the block the contribution made by the higher terms in the expression for P becomes insignificant. Hence we may confine ourselves to the three terms

$$P = X_1\sin z + X_3\sin 3z + X_5\sin 5z$$

Integrating this between o and z we get

$$\int_o^\pi P\,dz = 2X_1 + \frac{2}{3}X_3 + \frac{2}{5}X_5 = M \text{ . say .}$$

To get the total load carried we must integrate M between $x = \cdot6$ and $x = 1\cdot2$.

But

$$\int_{0.6}^{1.2} M\,dx = (1.2 - 0.6)\,\overline{M}$$

where $\overline{M}$ denotes the mean value of M. To find this we have Weddle's rule that if $y_0, y_1, y_2, y_3, y_4, y_5$ and y_6 denote seven equidistant values of y, then the mean value of y is

$$\bar{y} = \frac{1}{20}(y_0 + 5y_1 + y_2 + 6y_3 + y_4 + 5y_5 + y_6)$$

Applying this rule we find in the present case that

$$\overline{M} = .09514 \times \frac{24\lambda U}{c^2\pi}$$

Hence the total load carried is

$$(1.2 - 0.6) \times .09514 \times \frac{24\lambda U}{c^2\pi} = .4361\,\frac{\lambda U}{c^2}$$

The length of the block is π centimetres, so that the load taken per lineal centimetre measured parallel to z is $0\cdot1388\,\frac{\lambda U}{c^2}$. In other words, the value of ϕ (equation 1, page 233 *ante*) for a rectangular block is $0\cdot1388$ when the ratio ρ of the side a to the side w is $\frac{0.6}{\pi}$.

To determine the centre of pressure we have to find the value of

$$\int_{0.6}^{1.2} M\,x\,dx = \int_{0.6}^{1.2} N\,dx$$

If

$$N = M\bar{x}\,.$$

Hence

$$\int_{0.6}^{1.2} M\,x\,dx = (1.2 - .6) \times \overline{N}$$

where $\overline{N}$ is the mean value of N. Determining this as before by Weddle's rule, we find that the centre of pressure for $\rho = \frac{a}{w} = \frac{0.6}{\pi}$ is situated at a distance $0\cdot431a$ from the trailing edge.

The frictional resistance to the motion exerted on any element $dx\,dz$ of the moving plane is

$$q\,dx\,dz = -\lambda\left(\frac{du}{dy}\right)_0 dx\,dz$$

Hence from equation (8), page 234 *ante*,

$$q\,dx\,dz = \left(\lambda\frac{U}{h} - \frac{dP}{dx}\cdot\frac{h}{2}\right)_0 dx\,dz$$

If we integrate this expression over the whole area we get for F the total frictional resistance

$$F = \frac{\pi\lambda U}{c}\cdot\log_e 2 + \frac{\pi}{2}\frac{\lambda U}{c}\cdot\phi\,.$$

so that the resistance per centimetre run (measured transverse to the line of motion) is

$$f = \frac{\lambda U a}{h_0}\left(\log_e 2 + \frac{\pi}{2}\phi\right)$$

which for the block under discussion is:

$$= 0.911\,\frac{\lambda U a}{h_0}$$

In the case of geometrically similar blocks the resistance per cm. run is independent of their absolute dimensions.

The method above adopted for solving the differential equation is the orthodox one of the pure mathematician. It has the advantage from his point of view of being valid throughout infinite space; but suffers from the great practical drawback of the final result being expressed as the difference of two nearly equal quantities, so that the expansions involved have to be evaluated to many decimal places.

In practice the engineer is not concerned with the value of functions outside of certain narrow limits, nor does it matter in most cases should the calculated results be even as much as 5 per cent. or 10 per cent. in error. It is thus permissible to adopt other and more direct methods of solving such equations, particularly as they are generally applicable even where orthodox methods fail. With this premise we shall show how the differential equations relating to lubrication may be solved by direct numerical attack, taking the case of a Michell block, where a (Fig. 6 *ante*) has the value 1 and $b = 2$, whilst the width is π.

From physical considerations we know that the general character of the curve representing the pressure along the centre line of the block (taken in a fore-and-aft direction) must be the same as in the case of a block of which the width (taken transverse to the direction of motion) is infinite. In this latter case Reynolds has shown that the pressure curve is given by an expression of the form:

$$B\,\frac{(x-a)(x-b)}{x^3}$$

where B is a constant. We shall assume that between the limits $x = a$ and $x = b$ the pressure curve along the centre line of a Michell block can be expressed in the same form, but with B a function of x instead of a constant. If, for example, we take the equation for X_5, *supra*, we may (neglecting for the moment the constants on the right-hand side) write it as:

$$\frac{d^2X_5}{dr^2} + \frac{3}{r}\cdot\frac{dX_5}{dr} - X_5 = \frac{1}{r^5} \quad . \quad . \quad (17)$$

If we assume now that

$$X_5 = B\,\frac{(r-5)(r-10)}{r^2}$$

where B is a function of r, the boundary conditions are satisfied, since X_5 is equal to zero, both when $r = 5$ and where $r = 10$. Substituting this value for X_5 in equation (17) the equation becomes:

$$15B - (r^3 - 15r^2 + 50r)B + (3r^2 - 15r - 50)B' + (r^3 - 15r^2 + 50r)B'' = 1.$$

Let us assume that between the limits $r = 5$ and $r = 10$:

$$B = B_0 + rB'_0 + r^2\frac{B''_0}{2} + r^3\frac{B'''_0}{6}$$

We have then to determine B_0; B'_0; B''_0; B'''_0; so as to satisfy approximately the differential equation between the limits with which we are concerned. The most logical method of doing this is to determine these values so that the square of the error integrated between the limits in question is a minimum.

The arithmetic then involved is, however, tedious and tiresome, and considerable care is necessary to avoid numerical errors. In practice it is better to

divide the interval between $r = 5$ and $r = 10$ into eight parts and to determine B_0, B'_0, B''_0 and B'''_0 so that equation (17) is satisfied for each of the odd divisions, that is to say, when $r = 5\frac{1}{8}$, $6\frac{1}{8}$, $8\frac{1}{8}$ and $9\frac{1}{8}$.

To do this we have to solve four simultaneous equations found by putting r equal to the above values in equation (17) and replacing B, B′ and B″ by their values in terms of B_0, B'_0, B''_0 and B'''_0. Before making this final substitution it is, however, convenient to change the variable from r to $m = + q r$, the value of a and q being such that $m = 0$ when $r = 5\frac{1}{8}$ and $m = 3$ when $r = 9\frac{1}{8}$. We thus get the following four equations, viz.:

$$\begin{aligned} 15555\,B_0 - 16160\,B'_0 - 5040\,B''_0 &= 512 \\ 28305\,B_1 - 4640\,B'_1 - 13200\,B''_1 &= 512 \\ 32055\,B_2 + 10720\,B'_2 - 15600\,B''_2 &= 512 \\ 20805\,B_3 + 29920\,B'_3 - 8400\,B'''_3 &= 512 \end{aligned}$$

Now the variable having been changed from r to m, we have:

$$B_m = B_0 + m\,B'_0 + m^2\,\frac{B''_0}{2} + m^3\,\frac{B'''_0}{6}$$

$$B'_m = B'_0 + m\,B''_0 + \frac{m^2\,B'''_0}{2}$$

and

$$B''_m = B''_0 + m\,B'''_0.$$

Hence, putting m successively equal to 0, 1, 2 and 3, the four equations reduce to:

$$\begin{aligned} 6222\,B_0 - 6464\,B'_0 - 2016\,B''_0 &= 204{\cdot}8 \\ 11322\,B_0 + 9466\,B'_0 - 1475\,B''_0 - 4321\,B'''_0 &= 204{\cdot}8 \\ 12822\,B_0 + 29932\,B'_0 + 27980\,B''_0 + 13192\,B'''_0 &= 204{\cdot}8 \\ 8322\,B_0 + 36934\,B'_0 + 69993\,B''_0 + 81225\,B'''_0 &= 204{\cdot}8 \end{aligned}$$

From these we find that:

$$B_0 = {\cdot}025063 \quad B'_0 = -{\cdot}008500 \quad B''_0 = +{\cdot}004848$$
$$\text{and } B'''_0 = -{\cdot}000420$$

Hence:

$$B_1 = {\cdot}019517 \quad B_2 = {\cdot}017798 \quad \text{and } B_3 = {\cdot}020085$$

Other values can be found if required by interpolation by the usual finite difference formula. Since:

$$X_5 = \frac{6\lambda U}{c^2} \cdot \frac{4}{\pi} \cdot B\,\frac{(x-5)\,(x-10)}{x^2}$$

we then get the following values:

	m =	0	1	2	3
	x =	$5\frac{1}{8}$	$6\frac{1}{8}$	$8\frac{1}{8}$	$9\frac{1}{8}$
$\frac{\pi c^2}{24\lambda U} \cdot X_5$ =		0·002218	0·002419	0·001580	0·000625

In a similar way we get as the solution of the equation:

$$\frac{d^2 X_1}{dx^2} + \frac{3}{x} \cdot \frac{d X_1}{dx} - X_1 = \frac{6\lambda U}{c^2 X^3} \cdot \frac{4}{\pi}$$

the following values:

	m =	0	1	2	3
	x =	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$
$\frac{\pi c^2}{2\Delta\lambda U} \cdot X_1$ =		0·03133	0·04572	0·03298	0·01149

Similarly, for the solution of the equation

$$\frac{d^2 X_3}{dx^2} + \frac{3}{x} \cdot \frac{d X_3}{dx} - X_3 = \frac{6\lambda U}{c^2 x^3} \cdot \frac{4}{\pi}$$

we get

	m =	0	1	2	3
	x =	$3\frac{1}{8}$	$4\frac{1}{8}$	$4\frac{1}{2}$	$5\frac{1}{8}$
$\frac{\pi c^2}{24\lambda U} \cdot X_3$ =		0·005828	0·007374	0·005046	0·001852

As before, the total load on the block is equal to

$$2\int_a^b \left(X_1 + \frac{X_3}{3} + \frac{X_5}{5} + \text{etc.}\right) dx$$

$$= 2\,(2-1)\left\{X_1 + \frac{\overline{X}_3}{3} + \frac{\overline{X}_5}{5} + \text{etc.}\right\}$$

where the — over the X denotes the mean value of that function taken over the interval from $x = a$ to $x = b$.

The appropriate formula of integration to use in this case is:

$$\bar{y} = \frac{103}{3,150}\,(y_0 + y_8) + \frac{22}{105}\,(y_1 + y_7) + \frac{58}{225}\,(y_3 + y_5)$$

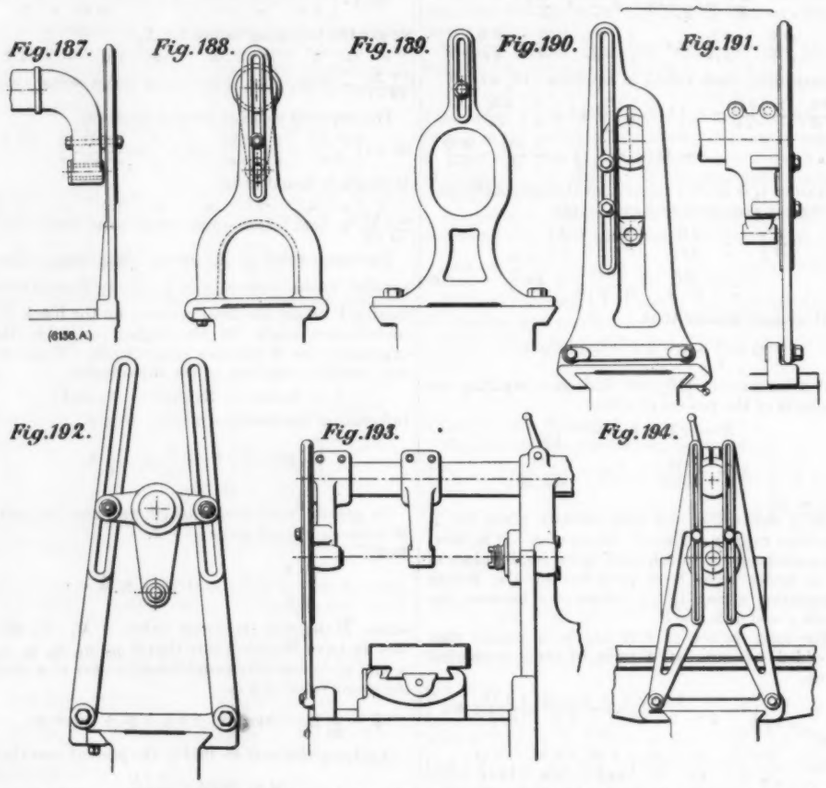
This formula assumes that the base of the curve to be integrated is divided into eight parts and that ordinates to the curve are raised at the odd points of division. It is valid in the same conditions as Weddle's formula; that is to say, when differences of the sixth and higher orders can be neglected.

The value thus obtained for ϕ is in this case 0·127.

RECENT MACHINE TOOL DEVELOPMENTS.—No. XI.

By JOSEPH HORNER.

Bracings.—With the increasing stresses imposed on cutting tools, greater attention has been given to the matter of affording adequate support to them. This has been noted in connection with the support provided for lathe tools by the forms of many beds, and double-tier designs. It is observable in the tool details of most turret lathes, and is seen in some gear cutters, in the forms of work-rests in direct opposition to the tools. Its greatest applications and diversities of form occur in the milling machines, and chiefly in those of horizontal-spindle designs. None of the early milling machines were provided with any support to the outer end of the cutter arbor, which was a cantilever only, carrying the cutter on its extreme end. But the early milling was always of a very light character. Not until heavy cuts were attempted was the need for an outer support felt.



The earliest design, that now known as the Lincoln miller, is a relatively simple one. The outer support is a plain upright—a housing which sustains the arbors at various heights, and in different longitudinal positions. The pillar and knee machines occur in a much greater variety. In these, the problem of bracing is complicated by the fact that the knee is adjustable for varying heights, which entails making provision for adjustments in the bracings. And these bracings, unlike those of the Lincoln machine, may interfere with the freedom of manipulation of the work, and its examination, since the workman stands in front of the knee. But some forms are less objectionable than others.

A good many of the lighter pillar and knee machines are made without bracings to the knees. Reliance is placed on the fitting of the deep vertical face of the knee to the pillar, and the support afforded by the elevating screw. The cutter arbor is sustained on its outer end in a bracket that is adjustable along a rigid arm, extending from the headstock, to accommodate cutters and their arbors of different lengths. These fall under one of two heads—the cylindrical, and the rectangular or prismatic section. The first is embraced by the tail support, to be tightened on it with a bolt in a split lug, the second has a flat face and vee'd edges, along which the tail support is slid. In a modified form the cylindrical arm with the tail-piece is slid bodily along split bosses in the headstock framing. Usually the upright members of the headstock are tied rigidly, either by casting them with an arch-piece, or by casting the overhanging arm in one with the arch-piece bolted on the uprights, or by the tightening of the cylindrical arm in split bosses. For a large volume of moderately-light duties these provisions are sufficient. The bracing together of the knee and overhanging arm was adopted in the first place in order to stiffen the milling machine for the work of gear-cutting. It is now included in all manufacturing machines, and others where moderately heavy duties are required.

Bracings must be readily removable if they are not to interfere with the rapid substitution of different classes of work on a table. The earlier braces were slotted bars, pivoted on the extreme corners of the knee, and crossing each other at the supporting arm in which the cutter arbor is pivoted or carried. A single tightening bolt, or two separate bolts are used. Many are made thus. The pivoted rods, crossing, accommodate themselves to variations in the height of the knee. Another design not very dissimilar is that of round rods going through split bosses on the corners of the knee, to permit of height adjustments, and fitting with eyes over the cylindrical overhanging arm that carries the centre for the cutter arbor. The adjustments in this case are the reverse of the first-named, being effected by the sliding of the rods through the bosses on the knee. Neither of these is regarded with much favour in view of the increased mass now put into manufacturing machines, and the general stiffening up that is required for high-speed work. Something more rigid is required.

Bracings for Pillar and Knee Machines.—These, as generally fitted, may be broadly grouped as single, and double slot designs. The objection to the first-named is that the brace comes in the way of the arbor support, and that it is less rigid than the second.

In Fig. 187 and 188 the brace fits over the knee with vee'd edges, and a take-up strip. Its single slot covers the vertical range of movement of the knee, and a single bolt secures it at any height.

In Fig. 189 the brace fits directly upon the knee, and differs from Fig. 188 in its outlines, the open space below the bolt giving free access to the arbor bolt. In Fig. 188 the slot comes in the way of the arbor support, and the brace must be removed for its adjustment. This fault is avoided in the Parkinson brace, Figs. 190 and 191, where the slot is set to one side of the centre. The two clamping screws used enter lugs cast with the arm or head bracket. The central clearance slot is made of sufficient width to permit of adjusting and tightening the bolt for the arbor centre. The brace fits to a sliding saddle that embraces the knee with vee'd edges.

Fig. 192 shows two independent braces, each pivoted to a saddle-piece bridging the knee. A cross-piece embraces the cylindrical overhanging arm, and it is clamped with two bolts in the slots. Its lower boss receives the bush that supports the outer end of the cutter arbor. Another variation is shown by Figs. 193 and 194. Two cast-iron slotted brackets are pivoted on bolts in a piece that grips the knee, and bolts in the slot holes enter lugs, Fig. 193, on the outer arbor support. The intermediate steady bracket supports arbors and cutters for gang work. Fig. 195 is a brace used on the heavy Hendey millers, both plain and universal, with two slots, and a clear space between. Two bolts go in each slot, to receive which, four lugs are provided on the arbor-supporting head. The slots measure 20 in. long, the base is 17½ in. wide. The base fits either directly to the knee as shown, or it is attached by two bolts to a bridge-piece.

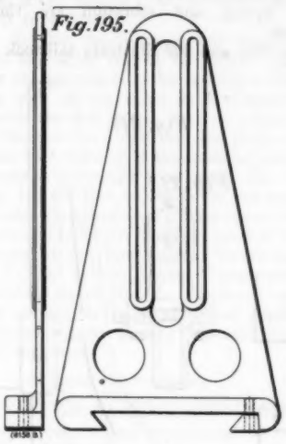
The Cincinnati brace in Fig. 196 is fitted over the horizontal arm. Two bolts secure it to the arbor bracket. The long slots go over the bolts that are fitted to the saddle of the knee. In addition, a diagonal brace bar is fitted across from slot to slot when the knee occupies its lower positions, in order to further reduce risks of vibration. The horizontal bar seen dotted, is cast with the brace to prevent the slotted arms from shrinking out of parallel. It is cut out afterwards.

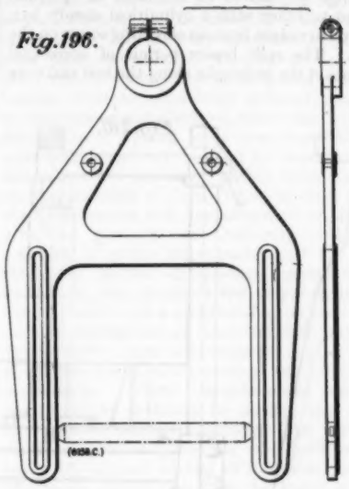
The example, Figs. 197 and 198, is that of a double brace which, with slight variations is used on a good many machines. The lower portion is fitted to the knee, the upper goes over the horizontal arm. Four bolts secure the two elements after the vertical adjustments have been made. The head portion carries the bearing for the cutter arbor. An intermediate support is provided for use when required for gang-milling.

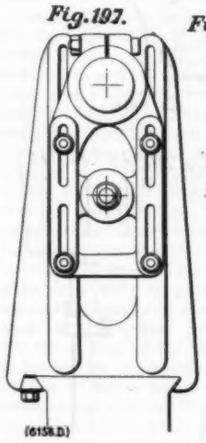
Vertical slots are duplicated in various ways. Figs. 199 and 200 illustrate a brace fitting to the knee with vee'd edges, having slots widely separated, and, in addition, the web is cambered, Fig. 199, in order to afford some clearance for the head of the arbor-supporting arm. Fig. 201 is a design in which the brace fits over the end of the overhanging arm with a split boss. The lower end of the brace is prolonged into slotted horns, through which bolts pass into the saddle on the knee. A clear opening is left below the tightening bolt for the manipulation of the arbor centre. An important advance is made in the design in Fig. 202, since the knee is braced both to the overhanging arm above, and to the base of the machine framing below. The previous designs have left the knee unsupported save for its elevating screw, but this binds the knee, the arm, and the base into one stable structure. The vertical movements of the knee take place through the range of the slots, and the tightening bolts go into the knee. Increasing numbers of machines are fitted thus, or similarly.

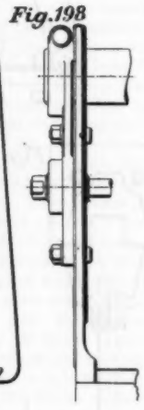
The form of bracing, of which Fig. 203 is typical is derived from some of the Lincoln designs. The end of the arbor is supported in the lower bearing which slides on, and is bolted to the face of the brace. This does not interfere with the movements of the workman in the same degree as one of the central designs does. A separate knee support may be included. In a modification of the form shown this is avoided. The brace is extended to, and bolted on the foot of the machine framing. The knee is adjustable on its vertical face, which is tee-grooved for the clamping bolt. A horizontal arm extends from the front of the headstock to the face of the brace. The outer arbor support is adjusted along this horizontal member, on which it is guided with vee'd edges.

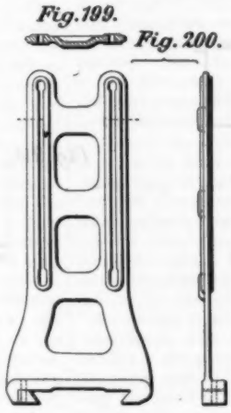
Lincoln Machine Braces.—An essential difference between the pillar and knee design and the Lincoln machine is that the vertical adjustments are

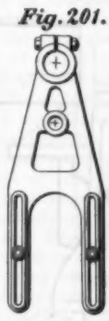


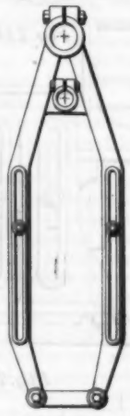


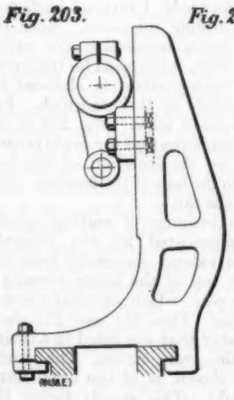


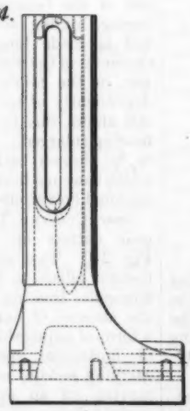


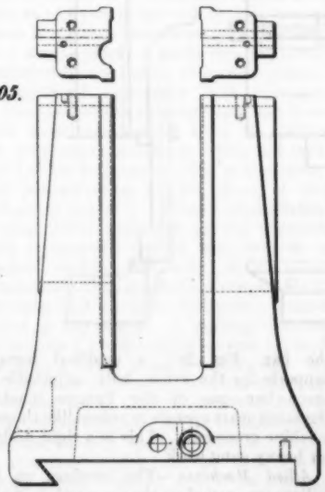


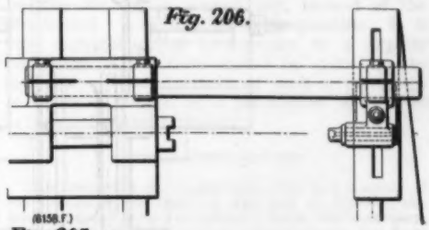


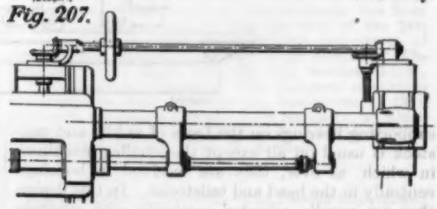












imparted to the work-carrying knee in the first, and to the cutter-driving spindle in the second. This is reflected in the forms of the braces used in each. In the Lincoln design the bracing occurs in the form of a stiff cylindrical bar, which ties the head and tailstocks together. This was not present in the earliest machines. It is stiff enough to maintain the arbor in alignment, when the spindle saddle is elevated by its hand wheel, since the bar, gripped in the saddle, is also carried in the sliding bearing in, or on the tailstock. The practice of carrying the supporting bearings on the faces of saddle and tailstock is usual on all except the smaller machines, in which, as ever, they are received in housings centrally in the head and tailstocks. In this design they are usually adjusted vertically with separate hand wheels and screws, with some loss of time and risks of non-alignment. But the best machines have micrometer dials.

The tail support of one of the Hendey machines is shown by Figs. 204 and 205. It fits on the bed with a vee and a flat, along which it is adjusted with a screw. The box-bearing for the tail end of the arbor slides on the flat vertical faces and edges, and is elevated and lowered by a screw, a recess for which is provided in the left-hand upright, Fig. 205. In addition to the support afforded by this screw, a binding bolt goes through the slots seen in the uprights, to clamp these and the box bearing as one piece after adjustment. A micrometer dial is fitted to the elevating screw, reading to thousandths of an inch.

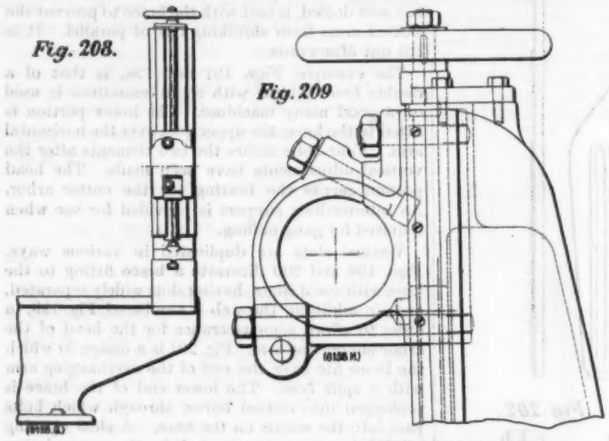
Fig. 206 shows how the arbor spindle supports and bearings are carried on the faces of uprights, and braced together with a cylindrical steady bar, to be moved in unison from an elevating screw on the headstock. The split bosses permit of horizontal adjustments of the tailstocks along the bed and over the bar. Fig. 207, a modified form, includes supports for the arbor, both adjustable along the brace bar—one of the Tangye machines. The elevating gears operate in unison like those of planing machine cross-rails. This is a rigid design suitable for heavy gang work.

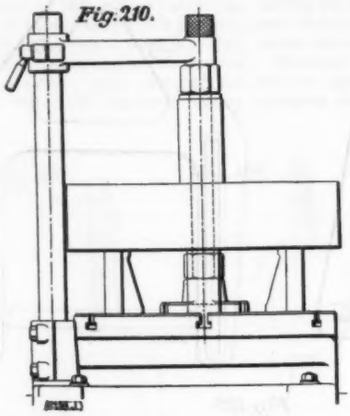
Allied Machines.—The bracings on the plano-millers are carried on the cross rail, being adjustable along it to afford support where required close to cutters. This is a necessary provision in the gang-milling done so extensively on these machines. Vertical-spindle machines, using edge mills are fitted with some kind of brace to steady the arbor below the cutter. These are either bolted or hinged to the main framing in the form of a bracket standing out; or they come down vertically from the sliding cutter-supporting head, being bolted to its bottom face and extending below the cutter to receive the tapered end of the arbor. Support is afforded to a tool close to the location where the greatest stress of cutting occurs by the use of a sliding support to the spindle or the arbor that carries the tool. None of the early machines included these provisions. Drilling machines afford abundant examples of this kind. Spring and vibration are thus greatly reduced.

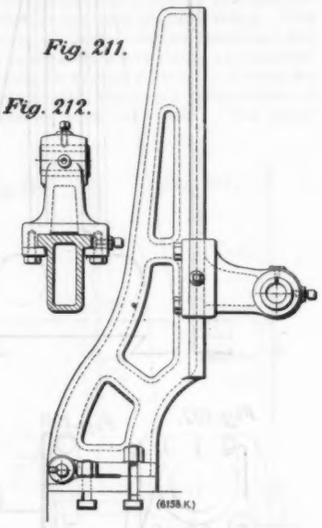
Figs. 208 and 209 illustrate tailstock details for one of the George Richards' Universal surfacing, boring, milling and drilling machines. Since the bed is made long, to accommodate the varied character of the work done, the support for the boring bar, or the milling cutter arbor, is elevated independently of the saddle on the headstock. Fig. 208 shows this to a small scale. Fig. 209 is the bearing enlarged. This shows that the cap is hinged, to be thrown back for the insertion of the bar, which runs in a bush in the bore of the bearing. The diagonal bolt secures the cap.

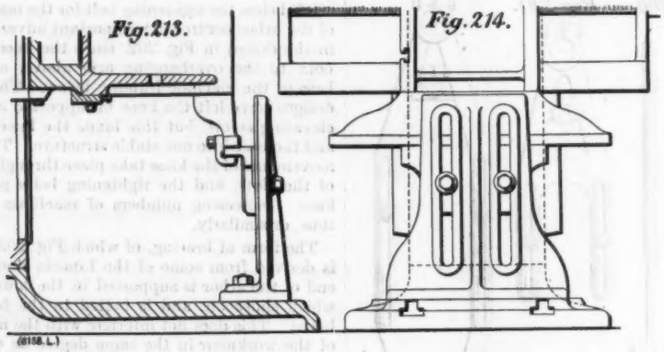
Gear Cutters.—The bracings of vertical spindle gear cutters are represented by the example, Fig. 210. Two arms extend diagonally from the upright pillars to the top of the arbor, forming a triangular framing in plan, which effectually resists the stresses of cutting. Figs. 211 and 212 show a form of adjustable stay that was fitted to a design of horizontal spindle gear cutter. The work-carrying saddle, not shown, is of the usual form, moving on an upright. This stands facing the upright shown, on which the bracket seen is adjusted with square edges and a setting-up strip. Its boss encircles the work-holding arbor or mandrel at its outer end, as will be readily understood without including a plan view. The base plate being clamped, the pivoted upright can be thrown back out of the way when the two front bolts in the slots, Fig. 211, are slid outwards.

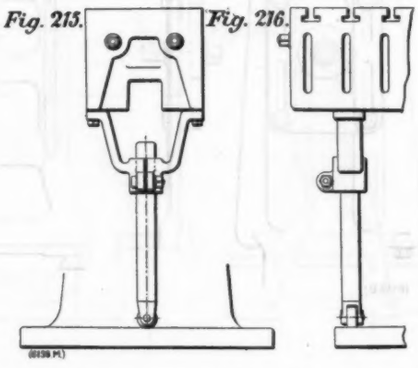
Shapers.—Supports for shaper tables are not so

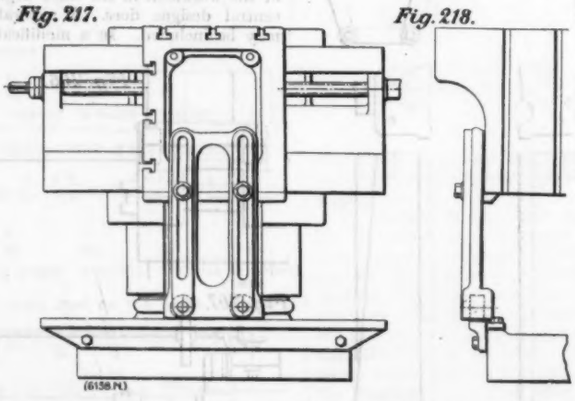












frequently fitted as one might anticipate. An example is illustrated in Figs. 213 and 214. An extension on the bottom of the knee, Fig. 214, provides a face approximating to that of the length of the slide-face of the machine framing. A bracket with two slot grooves for bolts is fastened to the base. Another bracket adjustable vertically sustains the extension piece, and is also gibbed to it, under the lip of the extension to the knee, in order to prevent it from lifting.

In some shaping machines a rod support is provided for the outer end of the table. Height adjustments are provided for by making a hole in the bottom web of the table with a split boss through which the rod passes, and in which it is clamped. The rod has a flat foot that slides along the baseplate with feeding of the table to push the cuttings away. Somewhat similar is the base, seen in Figs. 215 and 216, in which the rod support runs on a roller along the base. The upper end of the rod is gripped in a split boss in a bracket bolted to the bottom of the knee table. The design in Figs. 217, 218 is better, because more steady, since two rollers are employed. These are carried in a slotted upright on the inner face of which the knee is adjusted, bolts passing through the two slots to bind the parts.

SOME WATER SUPPLY PROBLEMS.

MOST of our great towns are situated at a considerable distance from the hilly districts of the kingdom where precipitation is large and the presence of lakes or valleys with narrow outlets makes the impounding of large quantities of water relatively cheap. It has thus been necessary for Manchester to seek its water supply from Thirlmere, situated nearly 100 miles from the city boundaries; Liverpool from Vyrnw, over 50 miles away, and Birmingham from the head waters of the Elan and Claerwent, some 70 or 80 miles distant. This annexation of gathering grounds by distant corporations has not been suffered without remonstrance from other communities. These being nearer the areas in question have held that they had a right to take exception to such appropriations, which in later years may make it necessary for them in their turn to draw their supplies from distant sources, owing to the nearer and more convenient gathering grounds having passed into the possession and under the control of far off cities. Again, as the more favourable areas are one by one appropriated, there has at times arisen a competition between different towns to secure the better of the remaining areas. Thus, a few years ago several corporations simultaneously promoted bills for securing water supplies from the River Derwent in Derbyshire. In this case matters were compromised by the formation of a joint water board to construct the works and allot the supply due to each of the constituents represented on the board.

This question of making the best use of our gathering grounds, and of reconciling the claims of competing communities has been the subject of several reports to Parliament by commissions or committees for the most part now forgotten. An interesting and useful digest of these reports, which have long lain undisturbed in their pigeon holes, is included in the Quarterly Circular of the British Water Works Association recently published. From this it appears that the matter was considered as far back as 1866, when the Richmond Royal Commission was appointed to ascertain "what supply of unpolluted and wholesome water can be obtained by collecting and storing water in the high grounds of England and Wales." This committee advised that the legislature "should jealously watch" any attempt by great cities to secure supplies from a distance, on the ground that other communities nearer the site might suffer. If the claim to a distant gathering ground were admitted the commission suggested that the promoters should be compelled to provide for the supply of all communities along the line of the aqueduct.

Another suggestion was that the towns in the different industrial areas should be arranged into groups, and that the supply from the nearest suitable area should be granted to the group rather than to any individual town.

In 1878 the Society of Arts, on the initiative of the late King Edward, promoted a further inquiry into this question. At that date little was understood as to the purification of water, and many held to be experts on sanitary questions, maintained that a supply once polluted remained polluted in spite of any further treatment it might undergo. This opinion, founded purely on a necessarily imperfect theory, was maintained in spite of the evidence to the contrary provided by the death rates from water-borne diseases in the different great cities, which showed that this was less in London with an admittedly polluted supply than in Manchester and Glasgow, where the water being derived from upland areas was considered to be pure and innocuous, needing no treatment before delivery to the consumer. With these views as to the impossibility of purifying water then in vogue, the preservation and due allotment of the upland gathering grounds was naturally considered a question of prime importance, and the schemes submitted to the adjudicators appointed by the Society of Arts involved the mapping out of the whole country into a number of water shed districts, each containing one or more complete river basins. These districts were to be under the control of a body of commissioners, with powers to acquire all existing waterworks. These commissioners would also constitute the authority for dealing with questions not only of water conservation but with sewage disposal, fisheries protection and flood prevention, under the central control of a Ministry of Health. The same general idea is to be found still earlier in the report (1867) of the Rivers Pollution Prevention Committee and its successor of 1868–74, and by many other bodies and committees since appointed. All, from the digest given, seem to concur in the advisability of taking steps to administer different water sheds as units, ignoring the existing Local Government Board boundaries.

Some of the earlier reports are fully as interesting as those by later commissions, and the digest includes long extracts from the report of the Royal Sanitary Commission of 1868–74. Some observations extracted from a paper by Lord Montagu, one of these commissioners, have a strangely familiar sound. Lord Montagu contended that water supplies should be in the hands of the community for the following reasons amongst others: "An elected municipality can be influenced by the inhabitants, who have the remedy in their own hands; a company is irresponsible, and complaint is useless and unheard. A municipality can seek only the good of the townsmen; a company seeks only to increase its dividends." Now there are some good reasons in favour of a municipal control of a water supply, at any rate in the case of large towns, but experience has shown that those quoted above, based as they are on purely *a priori* prepossessions, have been falsified by the facts. It is, for example, an almost universal experience that company officials are more responsive to complaints and treat complainants more courteously than do public officials. A corporation moreover "does not seek only the good of its townsmen," this is commonly a secondary consideration to the good of the predominant party in power. What is immediately popular is thus often preferred to the ultimate good of the community should this involve a certain present sacrifice. Finally, in the case of small municipalities, at any rate, a company will not run the risks that are light heartedly assumed by the elected of the people. A striking instance of this was furnished by the report on the typhoid outbreak at King's Lynn, some few years ago. It was there established that the corporation had been repeatedly warned by the Local Government Board, as to the dangerous character of its water supply, but had systematically disregarded the advice given. No company would have dared to act in the same way, as its directors, even if as wanting in the common feelings of humanity as Lord Montagu assumed, would have been afraid of at any rate a civil claim for damages, and possibly of a criminal prosecution should a typhoid epidemic result from their neglect.

The real advantage that a public authority possesses in regard to water supply, lies in the greater stringency with which offences in the nature of waste and pollution are punished by the magistrates when the undertaking is under direct public control; and further, in the circumstance that parliament will generally give a corporation powers to insist on a superior type of standard internal fittings than it will accord to a company. The writer well remembers the late Mr. W. B. Bryan, the engineer-in-chief of the East London Water Company, complaining that he was compelled to admit into houses in the area served by his company, water waste preventer cisterns of the flimsiest character, costing only about one-third of the cheapest admitted into houses by the corporations of the great provincial cities.

In this connection it may perhaps be well to point out that in another portion of the circular under review very grave injustice is done to Mr. W. B. Bryan. No doubt the passage in question escaped the notice of the technical editor, who would undoubtedly have cancelled it had he realised the insinuation conveyed. The passage in question is a quotation from "John Citizen" in the Municipal Journal of September 12, 1919. It runs "Every summer we get news of water shortage from many districts, but London never lacks an adequate supply now. Yet I can recall water famines in London, chiefly in the East End, but that was before the much-abused Metropolitan Water Board bought out the various private companies and so guaranteed water for all." This paragraph certainly conveys the idea that the water famine of a few years ago in the area served by the East London Company was due to the neglect of Mr. Bryan and his directors, whereas as a matter of history it was directly due to the action of the politicians then controlling the London County Council and the ignorance of the House of Commons. Mr. Bryan had in fact made arrangements for the construction of additional reservoirs in the Lee Valley, which, had his Bill passed Parliament, would have been in service before the great drought occurred. The Bill was rejected at the instance of the London County Council, represented in the House, amongst others, by the late Prof. Stuart, who urged in the House that the new reservoirs were totally unnecessary, because the East London Company had already a much larger storage capacity per head supplied, than any other London company. The speaker apparently could not realise that a much larger storage capacity was necessary for works supplied from a small river like the Lee, than from a large river like the Thames. The House, however, accepted the opinion put before them and the Bill was rejected. The result was, that when the drought ensued—a contingency for which Mr. Bryan had tried to provide—the public blamed him, instead of the ill-informed politicians really responsible. It is very regrettable that countenance to a popular perversion of the facts should be given by the inclusion without comment of such a paragraph as we have quoted, in a publication of a more or less professional character.

THE INSTITUTE OF TRANSPORT.—The first meeting of the Council of this Institute was held on Monday, the 9th inst., at the temporary offices, 2 and 3, The Sanctuary, Westminster, S.W. 1, and an announcement has been issued giving the names of the members of the first council, of the members of the various committees, of members and associate members of the Institute. The president is the Right Hon. Sir Eric Geddes, G.C.B., M.P., Minister of Transport. The inaugural meeting is announced to take place at the Institution of Civil Engineers, on Monday, March 8, or March 15, at which the president will deliver his presidential address. The hon. secretary *pro tem.* is Mr. H. E. Blain.

SHIPBUILDING IN FINLAND.—The Finnish shipbuilding industry has not been of much importance for a number of years, and was confined mostly to smaller vessels for coasting traffic. Last year, however, seems to mark a new departure. The newly-formed Atlantic Shipping Company has ordered three cargo-steamers from a Helsingfors yard, and the first vessel, named Finlandia, was recently launched. It has been built to the rules of Norwegian Veritas, and has a displacement of 2,370 tons. The engine was ready to be put on board at the time of launching. The cost, which was about 4,000,000 Finnish marks, appears to be rather high. Materials for the two sister ships have been ordered from Germany, and will be delivered promptly. The Atlantic Company has also ordered a fourth smaller boat of 760 tons.

LINK GRINDING MACHINE.

CONSTRUCTED BY MESSRS. L. STERNE AND CO., LIMITED, ENGINEERS, GLASGOW.

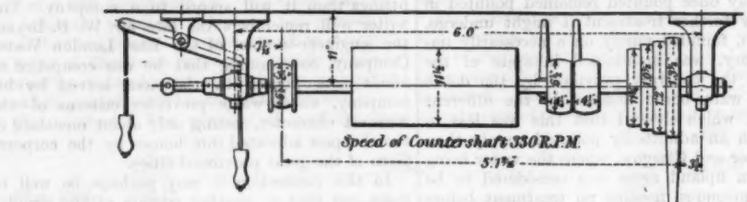


Fig. 1.

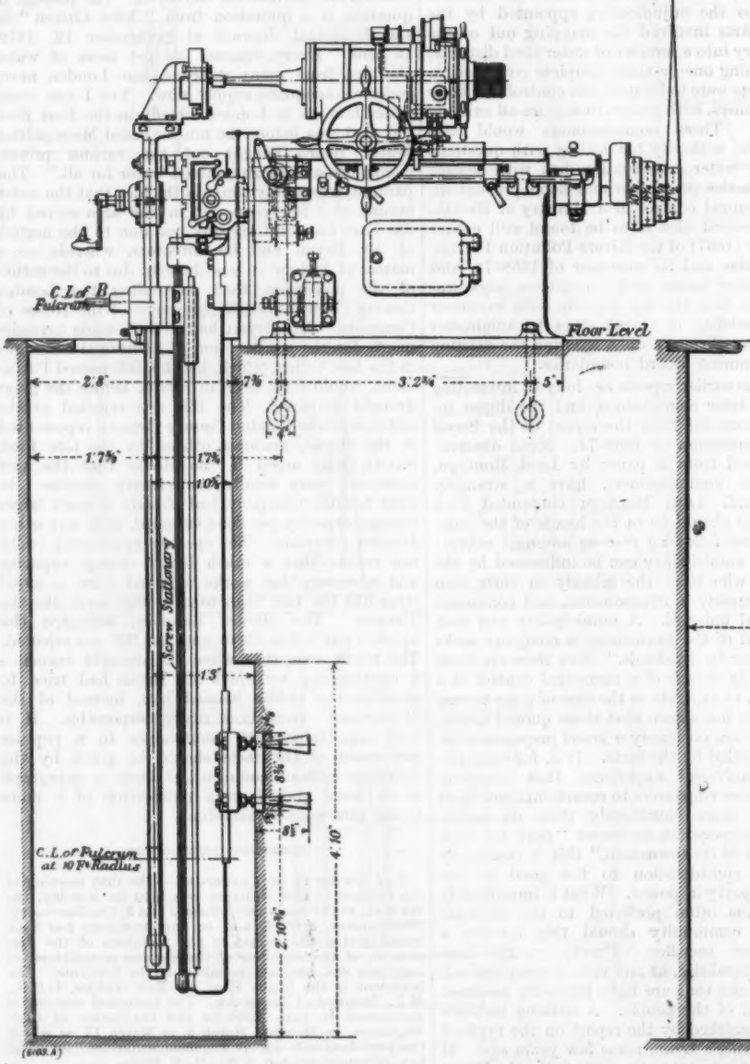
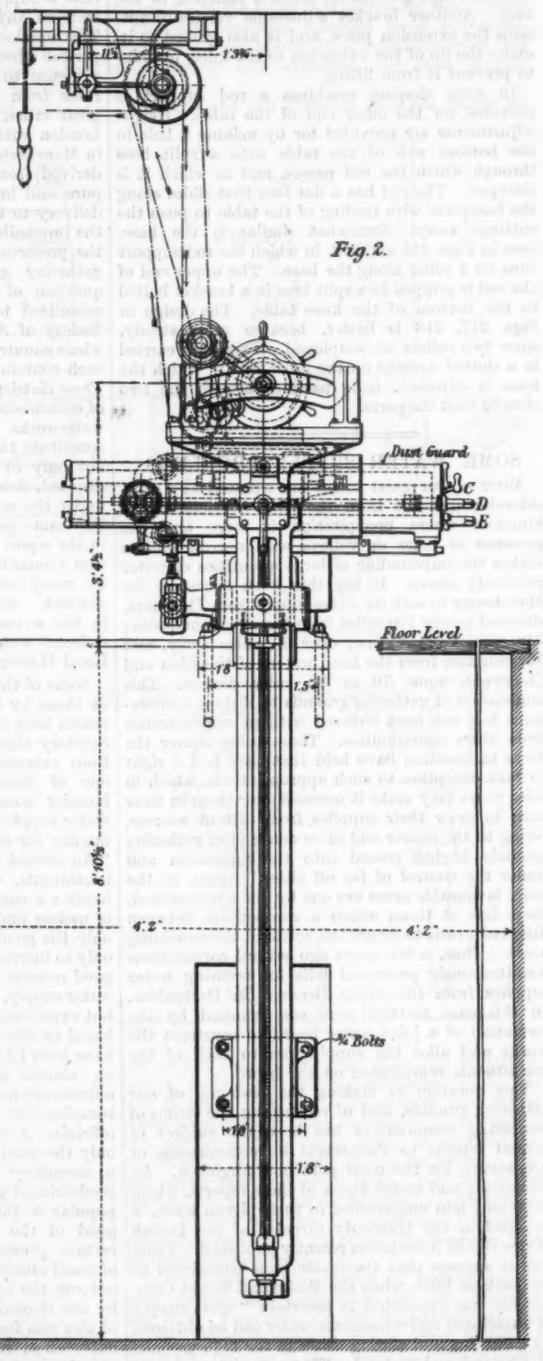


Fig. 2.



A LINK-GRINDING machine, constructed by Messrs. L. Sterne and Co., Limited, Crown Iron Works, North Woodside-road, Glasgow, is illustrated in Figs. 1 to 4 on the present and opposite pages. This machine, though mainly intended for locomotive links, is clearly useful for a wider range of work, as the radius possible varies between 2 ft. and 10 ft., while the machine can also be used for lapping and other work. The machine consists essentially of a box frame carrying the grinding mechanism, and the radius frame which is arranged vertically in a pit in front of the former.

Dealing with the grinding mechanism first, the grinding wheel has two speeds of 3,060 r.p.m. and 6,210 r.p.m. It is driven off a drum on the countershaft, which has a speed of 330 r.p.m. When grinding links, the wheel rotates on its own axis simply. When grinding round holes it has three movements. The first of these is on its own axis; the second is an eccentric motion which can be varied from 0 in. to 1½ in.; the third is a traversing movement of the whole head. The spindle runs in gun-metal bearings made adjustable for wear by means of a screw. The spindle is carried in a cast-iron sleeve which is mounted in a rotating outer casing. The sleeve can be thrown out of the centre of the outer casing. This can be done by automatic means, or by hand, without stopping the machine. A graduated disc reading to 1/1000th of an inch allows of accurate setting. The wheels used are from 1 in. to 2 in. by 2 in. and 3 in. and 4 in. by ½ in. The belt drive for the spindle can be seen in Fig. 2 and the two views, Figs. 3 and 4.

The whole grinding head moves on slides on the top of the body. The traversing movement of the grinding head is secured from the belt drive shown at the right-hand end of the machine in Figs. 1 and 3. This gives four speeds to the head, viz., 6·32 in., 7·67 in., 9·48 in. and 11·83 in. per minute. This movement can be controlled by adjustable stops, which are clearly seen in Figs. 1 and 3, on the near side of the body. This automatic movement can be thrown out of gear instantaneously, and hand movement substituted, operated by the large hand wheel on the near side of the

LINK GRINDING MACHINE.

CONSTRUCTED BY MESSRS. L. STERNE AND CO., LIMITED, ENGINEERS, GLASGOW.

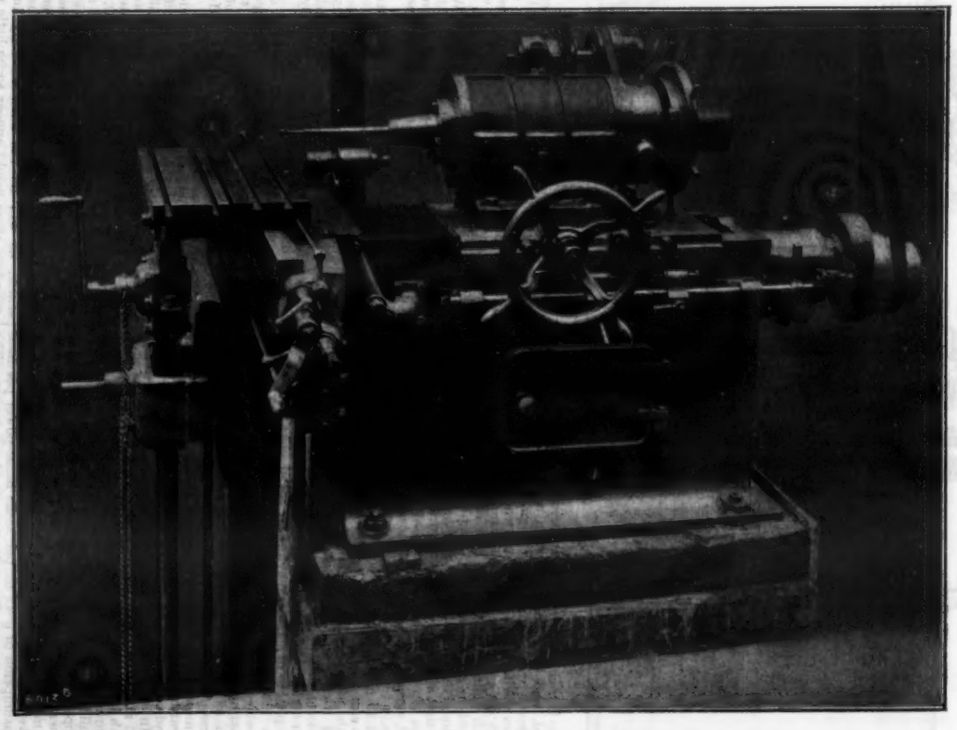


FIG. 3. SIDE VIEW.

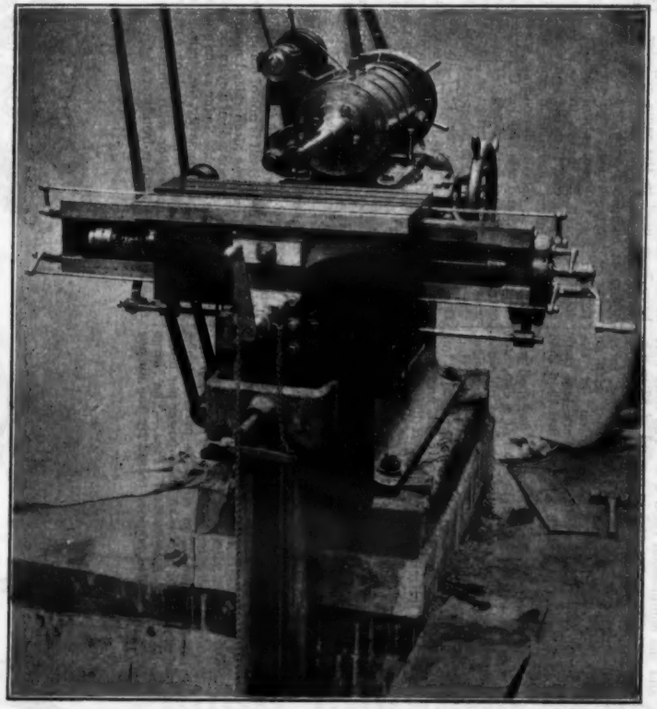


FIG. 4. FRONT VIEW.

machine in the same two figures. The work-table consists of two parts, providing both vertical and horizontal movement. The first is secured on wide faces on the machine body front. The second is obtained by the work-table itself moving sideways on the horizontal slide. The slides and wearing faces of the former are best seen in Figs. 1 and 3, and the horizontal faces for the work-table are most clearly seen in Figs. 2 and 4. The vertical cross-slide is raised or lowered by hand, by means of the spindle E, Fig. 2. The horizontal movement is either automatic by belt drive, or by hand by means of the spindle D. The automatic traverse is secured by a pulley and bevels at the left-hand end of the cross-slide, Figs. 2 and 4. The belt is led from the small 6¼ in. pulley at the left-hand end of the countershaft, over an idler on a curved arm, to the driven pulley, thence over another idler and tension gear back to the countershaft. The work-table is provided with catches to engage adjustable stops on a striking bar below the cross-slide. This reverses the movement of the table, by disengaging one bevel and engaging the other. The handle C throws the clutch out of gear and stops the table in any position of its traverse. When grinding holes or straight links the work is carried direct, or by angle plates attached to this table.

For radial-link grinding the work is carried on a second table worked by a pin on the face of that already described. This pin may be seen in Figs. 3 and 4. A block on it works in a slide in the radial table in order to allow for the difference in vertical movement of the latter. The radius table is carried by an adjustable radius bar working on a fulcrum, which is capable of wide vertical adjustment on a fulcrum frame attached to the vertical slide on the front of the machine already referred to. The fulcrum frame moves in slides placed in the pit below the machine. These are shown in Figs. 1 and 2. On this fulcrum frame is a long vertical fixed screw. Working on this screw is a nut carried by the fulcrum head B. This nut is geared with a screw on the radius bar, which is shown most clearly in Fig. 2. The screw is rotated by the crank handle A and works the fulcrum block B up and down on the fixed screw carried by the fulcrum frame, and most clearly seen in Fig. 1. A pin projects from the fulcrum head. This takes the eye of a telescopic measuring rod used for setting to the desired radius. This, as already noted, ranges between 2 ft. and 10 ft.

As soon as the fulcrum is set, the screw in the radius bar is disengaged from the fulcrum gear by a small cross-lever operated by chains so that this can be done whatever the position of the fulcrum head. When thus disengaged, and the radius set, the handle A can be used to move the work-table up or down, to feed up to the link to grinding wheel, as desired.

The working surfaces are covered by metal dust-guards. Those for the cross-slide are carried by rods, which may be seen in Figs. 3 and 4. The shield for the traversing slide of the grinding head is a canvas one, carried on a roller. It rolls up and unrolls off this as the head moves to and fro'.

THE INSTITUTION OF ELECTRICAL ENGINEERS: ANNUAL DINNER.—The annual dinner of this Institution will take place at the Connaught Rooms, Great Queen-street, W.C., on Thursday, March 4. Applications for tickets should be made to the Secretary of the Institution of Electrical Engineers, No. 1, Albemarle-street, W. 1, not later than Saturday, February 28.

THE AIR COOLING OF PETROL ENGINES.*

By A. H. GIBSON, D.Sc., University College, Dundee.

(*Concluded from page 213.*)

19. *Cylinder Design and Construction.*—An air-cooled cylinder with aluminium head is necessarily of composite construction, since the valve seats and the working surface of the cylinder barrel must be of some harder material than aluminium. Several types of composite construction have been tried with varying degrees of success. The valve seats may consist of rings of steel or of bronze, and these may be either cast or expanded into position. Both methods and both materials have been used with success. Owing to the relatively higher coefficient of expansion of bronze, such seats are less likely to come loose under operating temperatures if expanded in than are steel seats. One type of composite construction is shown in Fig. 1 on the next page. Here the aluminium casting forms the head and surrounds the greater portion of the cylinder barrel. The latter consists of a steel liner which is shrunk into the casing at about 300 deg. C. The casing itself is finned, and

* Paper read before the Institution of Automobile Engineers, January 29, 1920.

provides the barrel cooling surface. Several cylinders of this type, with diameters up to 4·75 in., have been tested, and have given excellent results. On the other hand, the relatively high coefficient of expansion of the aluminium alloys (0·000024 as compared with 0·000012 for steel) tends to cause separation of the liner and casing at working temperatures, and this causes overheating of the liner and consequent drop in power and increase in petrol consumption. Some few cylinders have developed such trouble, which has always been traced to a badly-fitting liner. This drawback becomes proportionately less important as the cylinder diameter is diminished, and for smaller diameters than 4 in. there is little reason to anticipate any difficulty of this kind. A shrinkage allowance of about 1 in 600 on the diameter should be given.

The method of inserting the liner appears to be important, and better results are obtained when the cylinder is heated in hot air to the required temperature, than when heated in an oil bath. In the latter case the presence of the film of oil between casing and liner is probably responsible for a certain lack of thermal contact.

Tests on bronze liners have been made, and by this means expansion troubles may readily be overcome. The wear of such a liner is, however, greater than that of a steel liner, though it is probable that investigation may enable a sufficiently hard liner of this type to be developed.

20. Tests have also been made with screwed-in steel liners, but with unsatisfactory results. Such cylinders have always given very high oil temperatures, indicating a hot liner, and on cutting the cylinder open after operation, lack of satisfactory contact between the liner and the casing has always been evident. The difficulty of obtaining good contact at all points of a long screwed liner is very great, and if satisfactory contact be obtained when cold, the difference of longitudinal expansion when hot causes the threads to touch only at isolated points.

21. In a third system of composite construction, the aluminium casting has been confined to the cylinder head, and into this has been cast or screwed the steel barrel with its own steel cooling fins, as shown in Fig. 2. Mechanically this system has proved sound. The cast-in barrel has been used successfully in sizes up to 6 in. diameter, and the screwed-in barrel in sizes up to 5½ in. diameter. The holding-down bolts now grip a ring, integral with the steel barrel. With a screwed-in barrel, the length of the screwed portion should be about one-fourth of the cylinder diameter.

22. In another system, exemplified in a well-known series of engines, the barrel and head are formed of steel in one piece. An aluminium cap embodying the inlet and exhaust ports is secured to the cylinder head by a series of bolts. This type is intermediate between the aluminium-headed cylinder and the all steel cylinder.

23. The author has had the opportunity of carrying out extended tests on the type of all-steel cylinder used in the Clerget, Le Rhone and other well-known aero engines. These tests have been on cylinder diameters ranging from 4 in. to 6 in. The tests show that for such sizes the all-steel cylinder gives very appreciably higher petrol consumptions than does the aluminium-headed cylinder, and that the brake mean effective pressure is lower. An interesting series of tests has been carried out by the author on a series of three cylinders differing only in the construction of the head. In one case this was of steel, with one aluminium inlet and two cast-iron exhaust ports bolted to its outer surface. In the second, Fig. 3, an aluminium cap was fitted to the head of the same cylinder; and in the third, Fig. 4, the original head was cut off and an aluminium head was cast on to the same barrel. The cylinder diameter was 5½ in. by 6½ in. stroke, and the compression ratio 4·6. The tests were carried out at 1,450 r.p.m., and in a wind of 82 m.p.h. The results showed that under maximum load conditions the aluminium-headed cylinder gave 15 per cent. more power than either the steel cylinder or that with an aluminium cap. The petrol consumption of the aluminium-headed cylinder was 26 per cent. less than that of the steel cylinder and 20 per cent. less than that of the capped cylinder.

It is true that the cylinder as originally designed was not very well adapted for the application of a cap, and probably appreciably better results could be obtained with this cap forming an integral part of the design. The author's experience, however, tends to show that unless such a cap is well bedded, the cylinder head is but little cooler than with the normal steel head, and that, however well fitted initially, "growth" and distortion of the aluminium cause lack of contact after some hours' running. Unless the cap be then rebedded the power falls off and the petrol consumption increases very appreciably.

The largest all-steel cylinder so far tested by the author and his colleagues has a bore of 6 in. and a stroke of 8 in. With a compression ratio of 4·48 and in a wind of 75 m.p.h. this cylinder, Fig. 5, developed 115 lb. brake mean effective pressure on a petrol consumption of 0·68 lb. per brake horse-power per hour, at 1,250 r.p.m., and 105 lb. mean effective pressure on the same consumption at 1,600 r.p.m. It had a single water-cooled exhaust valve 2·75 in. diameter. Under similar conditions an aluminium-headed cylinder of the same size developed 121 lb. brake mean effective pressure on a consumption of 0·56 lb. per brake horse-power per hour.

24. *Cylinders with Longitudinal Fins.*—The large majority of the air-cooled engines tested by the author have had circumferential fins surrounding the barrel and head, and have been tested in a free air blast. Two, however, were of different design, with longitudinal fins down the barrel. One of these was a Franklin car engine, with six cylinders, 3½ in. (92 mm.) bore by 4 in. stroke. Each cylinder carries a series of 56 parallel steel fins, 0·064 in. thick, 0·785 in. deep and 8 in. long. Each cylinder is surrounded by a cowling closely fitting the fin tips, Fig. 6, and air is drawn through these cowlings from top to bottom by a fan having a diameter of 20 in. and a width of 4 in. The mean air speed between the fins is 18 m.p.h., with an engine speed of 1,200 r.p.m., and 23 m.p.h. with a speed of 1,600 r.p.m. The engine has cast-iron pistons. Owing to the very small clearance of the pistons in two of the cylinders, namely, 0·0020 in. and 0·0025 in., it was found impossible to run this particular engine at full throttle for more than 10 minutes at a higher speed than 1,200 r.p.m. At any higher speed the pistons in these two cylinders seized. At 1,200 r.p.m. the brake horse-power was 26·7; the brake mean effective pressure was 70 lb. per square inch, and the maximum cylinder temperature 190 deg. C. Over a short run at 1,400 r.p.m. the engine developed 30·3 brake horse-power, falling to 24·9 brake horse power in 10 minutes, when the pistons seized. The maximum temperature half-way through this run was 251 deg. C., the wind speed being 20·5 m.p.h.

In the second cylinder of this type the bore was 110 mm. and the stroke 140 mm. This had a steel liner with an aluminium casing, carrying a series of 100 sheet aluminium fins 0·032 in. thick on the barrel, and 34 similar fins on the head. In this case the cooling air was supplied under a pressure of 2·5 in. of water, and passed upwards between the fins with a mean velocity of 50 m.p.h. With a compression ratio of 5·2, this cylinder developed 116 lb. brake mean effective pressure on a consumption of 0·49 lb. per brake horse-power per hour at 1,800 r.p.m., giving 21·4 brake horse-power. The maximum cylinder head temperature was then 261 deg. C. This cylinder had a single inlet and a single exhaust valve, both overhead.

25. *Pistons.*—Various types of piston have been used in the different tests. In many cases different pistons have been used in the same cylinder. The results all point to the general advisability of the aluminium alloy piston as compared with one of steel or cast-iron. A series of temperatures taken on different pistons in a 100-mm. by 140-mm. aluminium air-cooled cylinder, developing 115 lb. brake mean effective pressure at 1,800 r.p.m., showed that the temperature of the crown of an aluminium piston of normal design, with a full skirt and with splash lubrication, was about 200 deg. to 250 deg. C., and was 200 deg. C. lower than that of the corresponding cast-iron piston. The brake horse-power was 6 per cent. greater with the aluminium piston, and the petrol consumption 5 per cent. less. The weight of the cast-iron piston was 1·77 lb. and that of the aluminium piston 1·26 lb. The maximum clearances (cold) were 0·020 in. for the cast-iron piston and 0·026 in. for the aluminium piston. The clearances hot were sensibly the same, namely, about 0·008 in. These pistons are shown in Figs. 7 and 8. The cold clearance necessary over the top lands of an aluminium piston in a well-designed air-cooled cylinder is about 0·005 in. per inch of cylinder diameter.

26. *Cylinder Distortion.*—Other things being equal, cylinder distortion will be proportional to the difference of temperature between its hottest and coldest sides. Temperature distortion of the head itself is not usually serious, if the head itself is not of composite construction. One of the objections often raised against air cooling is that an air blast on one side of a cylinder leads to excessive distortion of the barrel. So far as the author's experience goes, this is not necessarily, or, indeed, generally, the case, at least with finned steel or cast-iron barrels of reasonable thickness, or with finned aluminium casings fitted with steel or cast-iron liners.

Fig. 1.

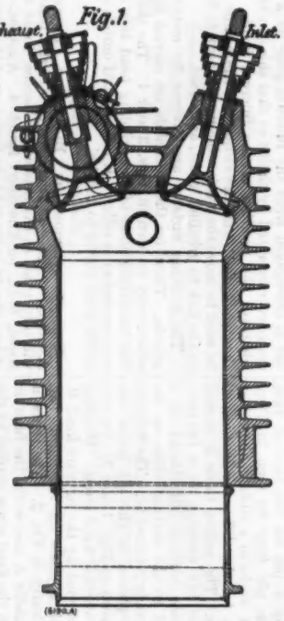


Fig. 2.

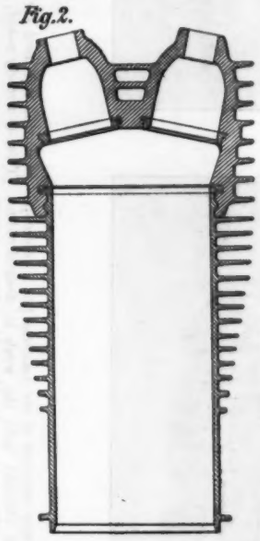


Fig. 3.

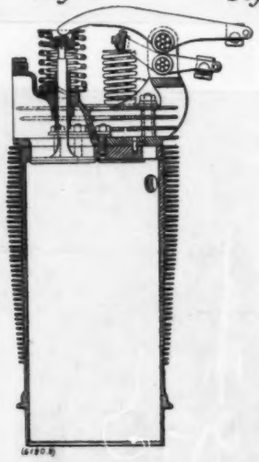
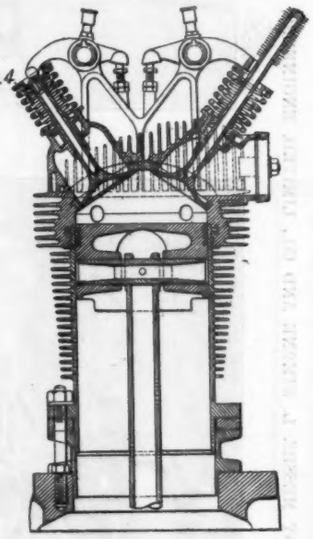


Fig. 4.



In such cylinders the differences of temperature between the two sides of the barrel depend entirely on the way the blast is applied. The exhaust side is normally the hottest, and by applying the blast to this side, the difference of temperature between the two sides may become comparatively small. As an example, the following figures taken from tests on a 5½-in. air-cooled aluminium cylinder may be of interest. With the blast on the exhaust side of the cylinder, the maximum difference of temperature between the front and back of the barrel was 58 deg. C., while the mean difference was only 19 deg. C. With the blast on the opposite, the inlet, side, the difference of temperature rose to a maximum of 180 deg. C. and a mean of 120 deg. C. In spite of this, however, the cylinder, which was fitted with an aluminium piston having only 0·025 in. clearance, showed no signs of binding after a prolonged run, showing that even in this extreme case and in a cylinder of this size, the distortion was not serious.

The results of a large number of tests on aluminium cylinders of 4 in. bore with the wind impinging on the side of the cylinder midway between the inlet and exhaust valves, show a mean difference of temperature of 56 deg. C. between front and back. Here, again, no evidence of distortion sufficient to have any practical effect has been noticed. A cast-iron cylinder of the same design and wall thickness gave a mean difference, under the same conditions, of 63 deg. C., while an L-head cast-iron cylinder of more normal design and wall thickness, also having the wind blowing across the cylinder, gave a maximum difference of 75 deg. C. and a mean difference of 68 deg. C. Here, again, the distortion had no apparent effect on the running of the engine. Since temperature differences are smaller with smaller diameters of cylinders, and since the effect of a given temperature difference is smaller as the cylinder barrel becomes stiffer, as will be the case normally in the smaller cylinders, there would appear to be little reason to fear the effects of distortion in any probable air-cooled motor car engine.

While a cylinder with longitudinal fins has a com

paratively even distribution of air flow around its periphery, this does not necessarily involve a lesser distortion. In the first place, with a cylinder of normal design the exhaust side is always the hottest, so that a cylinder with circumferential fins and a free air blast on its exhaust side will generally have a more uniform barrel temperature than one with longitudinal fins. Furthermore, the stiffening effect of the circumferential fins, of which the outer portions are comparatively cool, is very appreciable, and with a given temperature difference across the barrel the distortion of such a cylinder is much less than that of the cylinder with longitudinal fins.

27. *Fan Cooling.*—With a fan of the propeller or centrifugal type, the volume of air moved with a free inlet and discharge is sensibly proportional to the speed of rotation. When installed so as to draw or force air through a cowling, the delivery becomes proportional to N^x, where N is the number of revolutions per minute, and x is approximately 0·85.

For a constant cylinder temperature, the wind speed raised to the power 0·73 or $(N^{0·85})^{0·75} = N^{0·62}$, should be proportional to the heat to be dissipated. Over the range of speeds throughout which the volumetric efficiency is sensibly constant, and throughout which the brake horse-power and the heat to be dissipated are therefore proportional to the speed, the temperature of a fan cooled engine will increase with its speed of rotation.

Actually the brake mean effective pressure usually remains more or less constant up to about 0·66 of the speed giving maximum power, after which it falls off rapidly, with the result that the total heat to be dissipated at high speeds increases much less rapidly than the speed of the engine.

TABLE XIV.

Engine.	Speed—Revolutions per Minute.						
	800	1000	1200	1400	1600	1800	2000
Adler L-head :							
Cyls. 86 mm. by 135 mm.	1·02	1·04	1·06	1·07	1·06	1·04	1·00
Adler L-head :							
Cyls. 90 mm. by 125 mm.	1·05	1·02	1·02	1·02	1·01	1·01	1·00
Daimler-Knight Sleeve-valve							
Cyls. 96 mm. by 130 mm.	1·00	1·03	1·03	1·01	1·00	1·00	1·00
Mercedes-Knight Sleeve-valve :							
Cyls. 100 mm. by 130 mm.	0·83	0·87	0·92	0·96	0·98	0·99	1·00
R.A.F. 3 A. Aero :							
Cyls. 4·5 in. by 5·5 in. ..	—	0·95	0·97	0·99	1·00	—	—
S.C. Aluminium A.C. :							
Cyls. 4½ in. by 5½ in. ..	—	0·95	0·96	1·00	—	—	—

With a view of determining the effect of this, the author has obtained the values of the heat actually dissipated at different speeds up to the maximum load speed, for a series of engines. Taking the temperature difference between the air and the cylinder at this speed as unity, this difference has been calculated for lower speeds on the assumption that the engine is cooled by a fan of which the output varies as indicated above. The results are given in Table XIV. The data regarding the heat-loss from engines 1 to 4, are taken from tests by Riedler. Two of these engines are of the sleeve-valve type, and two of L-head type, both being motor car engines. The data for engines 5 and 6, which are of the overhead valve type, and of higher compression ratio, are from tests by the author.

The figures show that the cylinder temperatures in these engines would only vary slightly with the speed over this range. In the first three, the maximum temperature would be attained at about 1,300 r.p.m., and the engine would be actually cooler at higher speeds. In the last three, the maximum temperature would be attained at the highest speeds, but the speed effect is in no case very marked. It follows that the average car engine, if designed to cool when climbing on low gear at maximum engine speed, will be adequately, but not excessively, cooled under all other conditions, except in so far as it is affected by the cooling wind due to the velocity of the car through the air.

Since the average car engine seldom works at full throttle for more than a few minutes on end, it is a matter for consideration as to whether it may not be possible to cut down the fan capacity so as to allow of temperatures somewhat higher than those desirable under normal conditions to be attained during the worst conditions, as for example when climbing a long hill on low gear with a following wind. Assuming an air temperature of 20 deg. C., it may be taken that with a well-designed engine, the wind speeds given in paragraph 15 will enable a maximum cylinder temperature of approximately 240 deg. C. to be maintained. For short periods a maximum temperature of 280 deg. C. is permissible. The corresponding temperature-differences between the cylinder and the air are 220 deg. and 260 deg. C., the ratio being 1·18. Since this temperature-difference is inversely proportional to $V^{0·4}$, it follows that the wind speed may be reduced to $1/1·18^{2·4} = 1/1·18^{2·5} = 1/1·51 = 0·66$ of its normal value, without exceeding this higher limit of temperature-difference. The necessary wind speeds to be given by the fan at normal full engine speed in still air, should therefore be as in Table XV.

TABLE XV.

Cylinder Diameter, In.	Wind Speed, Miles per Hour.
2	20
3	25
4	33

It should be noted that these are the speeds necessary when the cylinders are of efficient type, well designed and with adequate cylinder lubrication; when the engine itself is efficiently exposed to the cooling blast, i.e., when each cylinder is freely exposed; when the blast is directed on to the hottest or exhaust side of the cylinder, and when there is free egress for the heated air.

28. *Power Absorbed in Cooling.*—Allowing a rise in temperature of 15 deg. C. for the cooling air during its passage over the engine, and assuming that 42 British thermal units are to be dissipated per minute from the engine surfaces per brake horse-power developed, this necessitates a volume, at atmospheric pressure and at, say, 15 deg. C., of 87 cub. ft. of air per minute per b.h.-p. At a velocity of 30 m.p.h. (44 ft. per second) the theoretical horse-power required to produce this cooling blast is only 0·006. The efficiency of these small fans, if well designed, is at least 50 per cent. or, allowing for frictional losses in the cowling, say, 40 per cent., so that the actual horse-power absorbed in cooling at full speed should not exceed 0·015 h.p. per engine brake horse-power.

In an engine with L-head cylinders, the horse-power absorbed would be about 50 per cent. greater than this, or 2·2 per cent. of the engine horse-power, while if the wind speed were doubled, allowing the same rise in temperature, the horse-power absorbed would be quadrupled, since the horse-power of a fan is proportional to the product of the weight of air and the square of its speed.

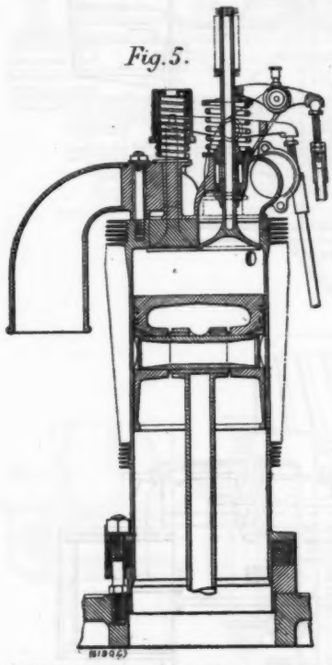
Some measurements of this fan power were carried out on a R.A.F. 5, twelve-cylinder Vee fan-cooled engine. Here the cylinders are of cast-iron and of L-head design. The brake horse-power is 140, the wind speed 60 m.p.h., and the fan, which is of the encased type, absorbs 9·25 h.p. at full speed, or 6·5 per cent. of the engine power.

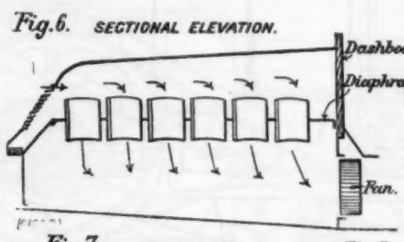
Tests by Riedler on the power absorbed by a cooling fan of the propeller type, used in connection with a water-cooled stationary tractor engine, gave the following results :—

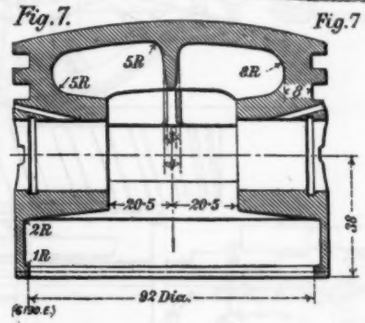
Fan speed-revolutions ..	710	900	1,030	1,140	1,240
Power absorbed (H.P.) ..	0·10	0·20	0·30	0·40	0·50

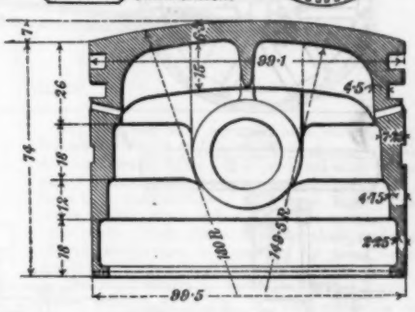
No figures are given as to the velocity of the cooling air, but at 1,240 r.p.m., with a power consumption of 0·5 h.p., the heat dissipated from the radiator was the equivalent of 23·7 h.p. The mean temperature of the radiator water was 75 deg. C. and the air temperature 16 deg. C. As the mean temperature-difference between the air and the cooling surfaces of the average air-cooled cylinder is at least twice as great as in this radiator, even if the efficiency of the cylinder surfaces, owing to their form, is only 75 per cent as great as that of the average radiator (a figure lower than is indicated by experiment) this fan would dissipate the heat from an efficient air-cooled engine of 22 h.p., absorbing 1·5 per cent. of the engine horse-power in the process.

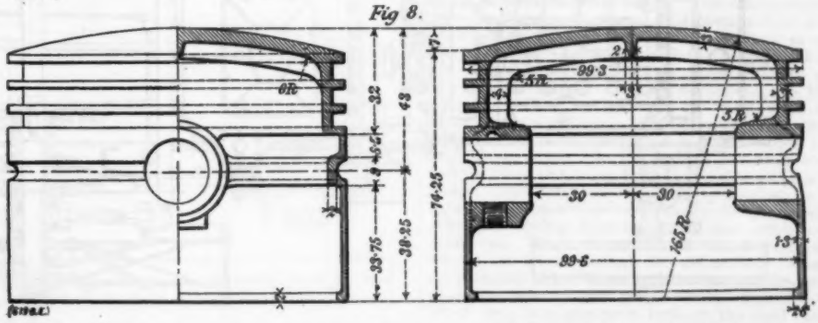
THE OPTICAL SOCIETY.—At the annual general meeting of the Optical Society, Mr. R. S. Whipple, M.A., was elected to the presidency. Professor F. J. Cheshire, C.B.E., Sir Herbert Jackson, K.B.E., F.R.S., and Mr. H. F. Purser, were elected vice-presidents. Mr. I. G. Aitchison as honorary treasurer, Mr. J. H. Sutcliffe as honorary librarian, and Messrs. William Shackleton, F.R.A.S., and L. C. Martin, B.Sc., as honorary secretaries.











30-H.P. FOUR-CYLINDER AGRICULTURAL TRACTOR.

CONSTRUCTED BY MESSRS. ALLDAYS AND ONIONS, LIMITED, ENGINEERS, BIRMINGHAM.

Fig. 1.

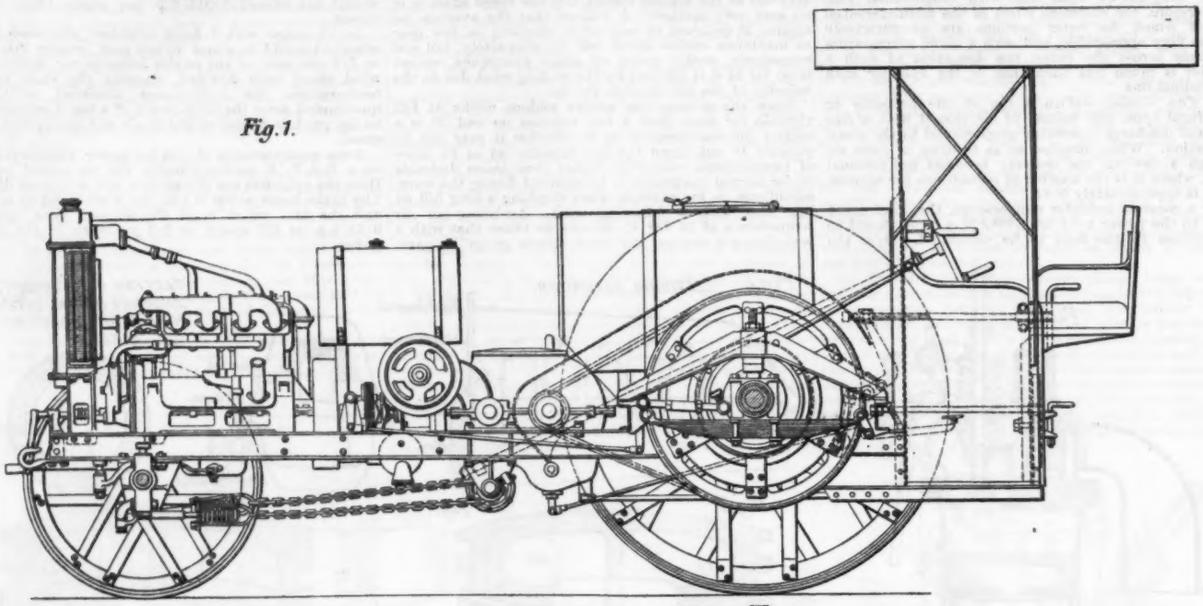
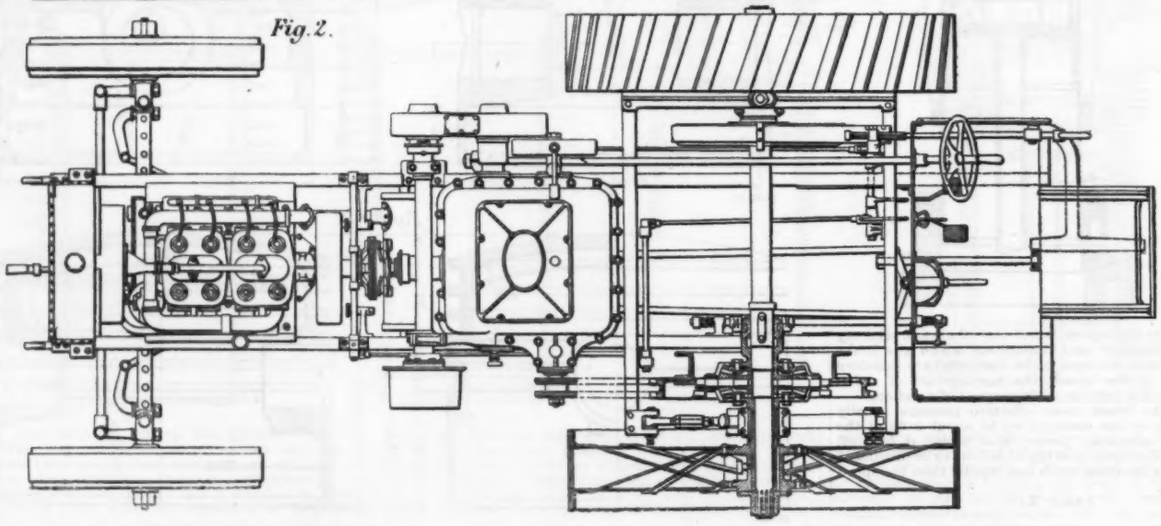


Fig. 2.



In the figures on this and the following pages we illustrate the 30-h.p. agricultural tractor which was entered in the recent Lincoln trials by Messrs. Alldays and Onions, Limited, of Birmingham. The intention of the designers of the tractor was to provide a machine suited for general purposes, and adapted more especially for road haulage and stationary work of different kinds, but capable of performing most of the work required for the tillage of land. In order to fulfil these functions properly and obtain the necessary adhesion, the weight of the tractor has not been cut as fine as in those designs which cater chiefly for tillage work and treat road haulage as a secondary matter. Great attention has accordingly been paid to the springing, and the rear axle has been mounted upon a pair of laminated springs, which can be put out of action when desired for work in the fields. A locking beam provided with a screw for this purpose is fitted over the rear springs. This can be seen in Figs. 1 and 2 and also in cross-section in Fig. 4, which shows the rear axle.

The steering is somewhat novel in form, being a combination of the traction engine and motor-car types. The front wheels are mounted on stub axles hinged on a built-up front axle, and are cross-connected through steering arms and a tie rod. Each stub axle is also provided with an additional steering arm connected to a cable chain which is wound upon a barrel operated from the drivers' seat through a worm and

Fig. 3.

DETAILS OF 30-H.P. AGRICULTURAL TRACTOR.

CONSTRUCTED BY MESSRS. ALLDAYS AND ONIONS, LIMITED, ENGINEERS, BIRMINGHAM.

Fig. 4.

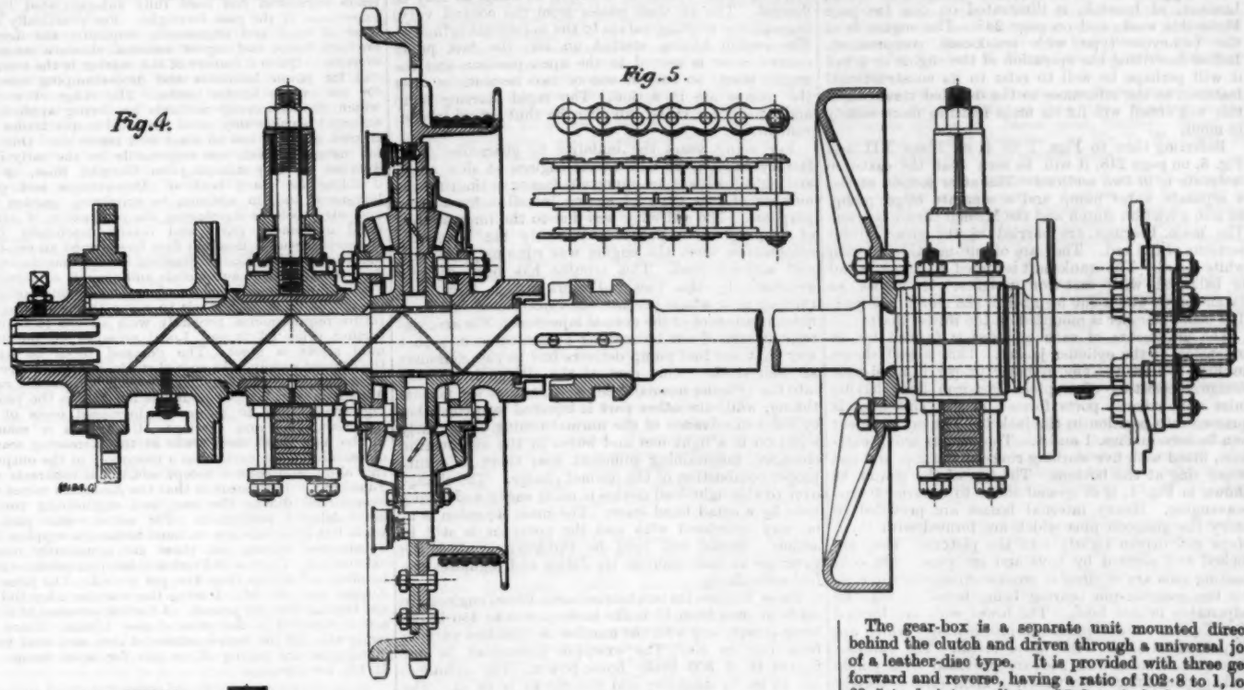
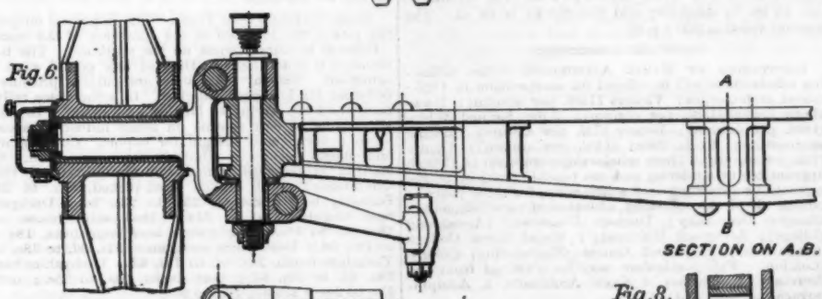


Fig. 5.

Fig. 6.



SECTION ON A.B.

Fig. 8.

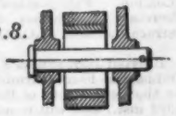
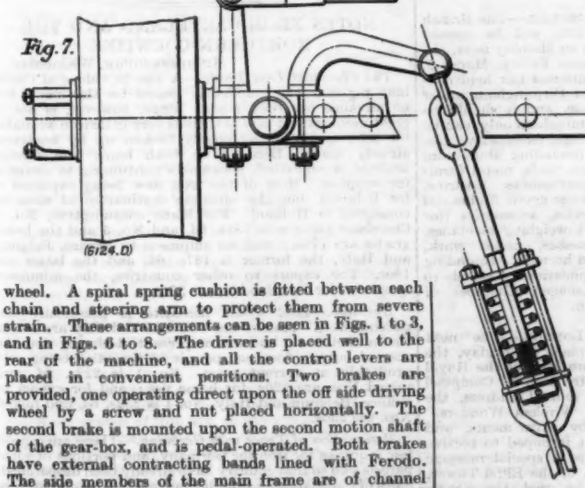


Fig. 7.



wheel. A spiral spring cushion is fitted between each chain and steering arm to protect them from severe strain. These arrangements can be seen in Figs. 1 to 3, and in Figs. 6 to 8. The driver is placed well to the rear of the machine, and all the control levers are placed in convenient positions. Two brakes are provided, one operating direct upon the off side driving wheel by a screw and nut placed horizontally. The second brake is mounted upon the second motion shaft of the gear-box, and is pedal-operated. Both brakes have external contracting bands lined with Ferodo. The side members of the main frame are of channel section straight throughout their entire length, and are united by cross-members, braced and gussetted. Towing hooks are provided at the front, and a box-shaped traction beam carries the drawbar attachment at the rear.

The engine is mounted at the front, and has four cylinders cast together, 4¼ in. bore by 6½ in. stroke. They are cast integral with the top half of the crank-case. The cylinder head is cast separately, and attached by studs and nuts, and can be readily detached for cleaning purposes. The whole of the valves, valve seatings and rockers are mounted in this casting. The engine is designed to run entirely on paraffin, and therefore has a low compression pressure in the neighbourhood of 60 lb. to the square inch. The bottom half of the crank-case is merely an oil seal, and carries the troughs for lubricating the big ends. The crankshaft is housed in five bearings lined with white metal. The flywheel is mounted upon a flange at the rear end, which is turned to receive a cone clutch lined with Ferrodo. The camshaft is mounted in the crank-case and driven by spur gears. The motion to the valve rockers on top of the engine is carried up by push rods. The magneto and water pump are driven by a cross shaft mounted on the front of the engine immediately behind the radiator, which is of a gilled tube type. A Holly carburettor is fitted. This is of a single-jet type, delivering the paraffin into an exhaust-heated vaporising chamber. The air is taken in through a well-arranged water seal to ensure proper cleansing and to prevent dust passing into the cylinders.

The gear-box is a separate unit mounted directly behind the clutch and driven through a universal joint of a leather-disc type. It is provided with three gears forward and reverse, having a ratio of 102·8 to 1, low; 69·5 to 1, intermediate; 35·2 to 1, high. They are made of Ubas steel, carbonised. The teeth are 6 pitch, 1½ in. wide. They slide on a square shaft, and the gear-change mechanism is operated by hand lever and quadrant, similar to motor-car practice. Final drive to the road wheels is by a Brampton double roller chain, illustrated in Fig. 5. The rear axle rotates, and is of quite a novel design. The arrangement is shown in Fig. 4. It consists of a circular steel shaft, extending right across the vehicle, castellated at each end to fit steel castings bolted to the road wheels, and through which the latter are driven. On the near side is mounted the chain wheel surrounding the bevel differential. Cast integral with the chain wheel is a drum to carry 50 yards of steel cable. One crown wheel of the bevel differential is bolted direct to a steel sleeve keyed into the hub of the road wheel, and the other to a sleeve forming one element of a jaw clutch. The latter sleeve is free to revolve on the axle until the other element of the jaw clutch is engaged. When the winding drum is required this clutch is disconnected. When the clutch is united both road wheels are driven through the differential. Another novel feature in the design is the carrying of the weight of the frame to the road wheels through a steel sleeve, which runs in a gun-metal bush on the steel casting upon which the springs are mounted. It will be seen on referring to the illustration, Fig. 4, that the rotating live axle is reinforced at this point, and its major duty is therefore to transmit the torque, and not to act as a girder to carry the weight of the machine. The pulley for driving stationary machinery is mounted on a separate gear-driven shaft.

THE INCORPORATED SWANSEA EXCHANGE.—The thirty-second annual report of the Incorporated Swansea Exchange, for the year 1918–19, has now been issued, at the price of 2s. 6d., by the *Daily Post* Printing Works, High-street, Swansea. It gives the articles of association, and also the balance sheet to June 30, 1919, the by-laws, lists of trades and members, list of tin-plate works, with brands, trade statistics, &c., all information which will prove useful to merchants for reference purposes.

DEOXIDISING MOLTEN IRON.—In a paper entitled "Cerium in Cast Iron," read before the American Foundrymen's Association, Dr. R. Moldenke states that while it is desirable to make iron as free from oxygen as possible so as to do away with deoxidisers, the use of such alloys is not only necessary but beneficial in some cases. In adding such alloys to molten iron, Dr. Moldenke said that the best method was to sprinkle the granulated material in the stream as it issued from the cupola or furnace spout. In this way, the alloy became red hot by the time it entered the ladle, and assimilated readily.

VICKERS-PETTERS SEMI-DIESEL MARINE OIL ENGINE.

A TYPICAL semi-Diesel four-cylinder marine engine of the type manufactured by Messrs. Vickers-Petters, Limited, of Ipswich, is illustrated on our two-page Plate this week, and on page 248. The engine is of the two-cycle type with crank-case compression. Before describing the operation of the engine in detail it will perhaps be well to refer to its constructional features, as the references to the detailed views which this will entail will fix its main features more clearly in mind.

Referring then to Figs. 1 to 4, on Plate XII, and Fig. 5, on page 248, it will be seen that the cast-iron bedplate is in two sections. The after section carries a separate water pump and a separate bilge pump, as also a friction clutch and the Michell thrust bearing. The main bearings are carried in the cross girder sections of the bed. They are of gun-metal lined with white metal. The crankshaft is forged in one piece and is balanced with cast-iron weights. It carries an extension to which one member of the clutch is keyed. The other member is mounted on the thrust shaft.

The crank-case of each cylinder is formed by an extension of the cylinder jacket. This is best shown in Figs. 1 and 4. The cylinder proper is of simple design, consisting of a plain cast-iron liner having inlet and exhaust ports formed in it. This liner is pressed into position in the jacket. The arrangement can be seen in Figs. 1 and 4. The pistons are of cast-iron, fitted with five working rings at the top, and one wiper ring at the bottom. The top of the piston, as shown in Fig. 4, is of special shape to ensure efficient scavenging. Heavy internal bosses are provided to carry the gudgeon pins which are formed with three steps and driven tightly into the pistons. They are locked and secured by keys and set pins. The connecting rods are of circular cross-section, the top ends for the gudgeon-pin bearing being bored to take an adjustable bronze bush. The lower ends are formed to a T-palm to take the crank-pin bearings, which are of gun-metal lined with white metal. The cylinder heads are of cast-iron and are provided with ample jacket space for cooling water. Their form is clearly shown in Figs. 1 and 4. These views also show the form and method of attachment of the vaporisers. These form the only uncooled portions of the cylinder heads. They are entirely separate units and are easily removed for inspection of the combustion chambers.

There are four fuel pumps consisting of bronze castings with hardened steel plungers. They are mounted at the aft side of No. 1 cylinder and driven from the crankshaft by eccentrics. The arrangement can be seen in Figs. 1, 3 and 5. The control of the fuel supply is by a shaft governor operating through these eccentrics. Hand control is also fitted, and by means of a lever working over a stepped quadrant, the stroke of the fuel pumps may be regulated to give the engine speed desired. Each cylinder is fitted with a reversing valve. These are operated by cams mounted on a shaft carried along the front of the engine. The shaft is driven through spiral gearing from the crankshaft, as can be seen from Fig. 5. The cams are provided with rises for ahead and astern rotation, and are also arranged with a neutral position. They are worked longitudinally along the camshaft to bring the valves under control of either the ahead or astern rises, as may be required. The cams are so disposed as to permit of starting the engine in either direction without barring round. A master valve is provided so that air is not open to the air valves during normal running.

The sprayer is of very simple construction without any mechanically-operated parts. Its function is simply to spray the oil delivered from the pump into the vaporiser. Exhaust silencers are bolted, direct to the back of the cylinders, as shown in Figs. 3 and 4. One silencer takes the exhaust from two cylinders. The silencers are water jacketted, as is clearly shown in Fig. 4.

For the water-cooling system each pair of cylinders is provided with a circulating plunger pump. The course of the cooling water is from the cylinders through the cylinder heads to the silencers, and thence overboard. Lubrication is by forced feed for the cylinders, gudgeon pins and crank pins, and by syphon for the main bearings. As already mentioned, the engine operates on the two-cycle principle, with crank-case compression. The scavenging air is led through a chamber in the cylinder jacket to the inlet ports. When these latter are uncovered the air rushes into the cylinder and blows out the exhaust gases, the exhaust ports being uncovered during this period. The scavenging is thus done with air only and not with fuel mixture as is not unusual in two-cycle petrol and gas engines.

To start the engine the vaporiser chamber is first heated. A rapid starting lamp is fitted which enables this to be done in a very brief period. The engine can be started from cold and be on full load in less than a minute. After the lamps are lit, the engine is started by opening the air valve from the reservoirs to the air control valve and moving the air starting lever, which throws the air valve into connection with the air-starting cams for ahead or astern running, as may be desired. The air then passes from the control valve through the starting valves to the individual cylinders. The engine having started on air, the fuel pump control lever is moved to the open position and the engine starts on fuel in one or two revolutions after the pumps are in action. The rapid starting lamp and master air valve can then be shut off when convenient.

For many years the inability to guarantee satisfactory running of semi-Diesel engines at slow speed and light load was an important factor in limiting the number of this type of engine installed for marine purposes. The difficulty was due to the impossibility of keeping the vaporiser sufficiently hot to ensure combustion when the engine was running dead slow and without load. This trouble has been entirely overcome by the Vickers-Petters patent light load running gear which permits the injection of fuel very much in advance of the normal injection. The arrangement is carried out by making a connection in such a way that one fuel pump delivers fuel to two cylinders at each stroke. One part of the charge is injected into the cylinder normally supplied, and at the normal timing, while the other part is injected into the other cylinder in advance of the normal timing. The early injection is a light one and burns in the combustion chamber, maintaining sufficient heat there to ensure proper combustion of the normal charge. The change over to this light-load device is made easily and at any time by a small hand lever. The main injection is in no way interfered with and the governor is still in action. Should full load be suddenly applied the governor at once assumes its duties and regulates the fuel accordingly.

These Vickers-Petters marine semi-Diesel engines are made in sizes from 10 brake horse-power to 450 brake horse-power, and with the number of cylinders varying from one to six. The example illustrated in our figures is of 300 brake horse-power. The cylinders are 16 in. in diameter and the stroke is 18 in. The normal speed is 250 r.p.m.

INSTITUTION OF NAVAL ARCHITECTS.—The following scholarships will be offered for competition in 1920: Naval architecture: Vickers (150*l.* per annum); Hawthorn Leslie (150*l.* per annum); John Samuel White (100*l.* per annum); Denny (75*l.* per annum). Marine engineering: R. L. Scott (150*l.* per annum); Denny (75*l.* per annum). These scholarships are open to British apprentices or students, and are tenable (subject to the regulations governing each scholarship) for three years at one or all of the following educational establishments: Glasgow University; Durham University (Armstrong College); Liverpool University; Royal Naval College (Greenwich); City and Guilds (Engineering) College (London). Full particulars may be obtained from the Secretary, Institution of Naval Architects, 5, Adelphi-terrace, London, W.C. 2.

BRITISH INDUSTRIES FAIR, BIRMINGHAM.—The British Industries Fair (Birmingham), 1920, will be opened by the Lord Mayor of Birmingham on Monday next, the 23rd inst., and will remain open until Friday, March 5. This is an integral part of the combined fair held concurrently at London, Glasgow and Birmingham under the auspices of the Board of Trade, and it should be noted that at Birmingham, and Birmingham only, can be seen the following: Lighting fittings (electricity, gas, oil), cooking stoves and utensils (including aluminium and enamel ware), general hardware, tools, metal furniture, perambulators, nautical instruments, firearms, fishing tackle, machine belting, rubber goods (industrial and household), cycles, motor cycles, accessories (for motor cars, cycles and aeroplanes), weighing machines, sanitary apparatus, paints, varnishes, metal work, ropes (steel and hemp), saddlery and harness. Intending visitors should make immediate application for tickets to Mr. Charles Stanley, General Manager, Chamber of Commerce, New-street, Birmingham.

THE WIRELESS SOCIETY OF LONDON.—The next meeting of this society will take place on Friday, the 27th inst., at 8 p.m., in the Lecture Hall of the Royal Society of Arts. The president, Mr. Alan A. Campbell Swinton, F.R.S., will deliver his annual address, the subject of which will be "Some Wireless Wonders." The address will be illustrated by experiments, and during the course of the evening it is hoped to receive and record in view of the audience a special message to the society from General Ferrie, of the Eiffel Tower, in Paris. No outside aerial will be used, the signals being received on the apparatus in the room. In the afternoon of the same day a conference of provincial wireless societies, which have recently become affiliated to the Wireless Society of London, will be held at 3 p.m., also at the Royal Society of Arts. The new book of rules and list of members is now published; it shows that since the society resumed activities after its long period of inaction due to the war, new members and associate members in very large numbers have been enrolled. Intending new members may apply for particulars of the society to the Honorary Secretary, Mr. L. McMichael, 32, Quex-road, West Hampstead, N.W. 6.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The forecast in steel-making circles that increased prices would not act as a deterrent to trade expansion has been fully substantiated by the experience of the past fortnight. For practically every class of steel and engineering requisite, the demand, on both home and export account, shows a consistent increase. Quite a feature of the market is the increased call for power hammers and drop-stamping machines for use in the lighter trades. The range of work to which drop-stamping methods are being applied, has enlarged considerably since the local staple trades were thrown more or less on their own resources. One firm, for instance, which was responsible for the early introduction of drop-stamping on German lines, is now doubling its plant both of drop-stamps and power hammers, and, in addition to supplying garden tools and edge tools, is developing the production of agricultural implement parts and textile machinery parts. In another case a Belgium firm has opened an establishment in the East End of Sheffield for the manufacture of drop stampings for automobile and aircraft construction. There is increasing evidence of anxiety among home and foreign users of mild steels to cover themselves against future requirements, probably with an eye to avoiding further price advances. Local pressure on output of mild steels is great. The demand tends to exceed the current supply. In special steels, business is growing rather more gradually. Here, again, prices are rising. An advance of 3*d.* per pound is notified in the price of high-speed steel to cover the increased costs of raw materials, fuel and carriage. Uneasiness is manifest in the high-speed steel trade at the increasing scarcity of vanadium. America has a monopoly of the output of this alloy, and cannot accept additional contracts until June next. The reason is that the American mines were overworked during the war, and engineering troubles have delayed production. For some weeks past the trade has been existing on hand-to-mouth supplies from Continental stocks, but these are apparently nearing exhaustion. Current deliveries of ferro-vanadium cannot be obtained at less than 44*s.* per pound. The price last August was 24*s.* 6*d.* During the war the alloy did not rise beyond 18*s.* per pound. A further advance of 1*l.* per ton is reported in the price of steel billets. There is a ready sale for the best qualities of iron and steel scrap. Merchants are asking 9*l.* a ton for steel scrap, and 7*l.* 15*s.* for turnings.

South Yorkshire Coal Trade.—The improved output at the pits is not reflected in the condition of the market. "General scarcity" sums up the situation. The home demand is much heavier than at any period since the armistice. Railway companies are putting pressure on collieries for increased supplies. In some cases railway companies are having to fall back on stocks. Increased allocations of best steams on home industrial account leave a very small margin for export. Cobbles, nuts, and slacks occupy a similarly strong position. Substantial arrears still remain in the house-coal trade. Quotations:—Best branch hand-picked, 23*s.* to 24*s.*; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.*; Derbyshire best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.*; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; best slacks, 24*s.* to 25*s.*; nutty, 23*s.* to 24*s.*; smalls, 19*s.* to 20*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—A rise in values of Cleveland pig-iron was confidently looked for this week, but no advance has been made. Price, however, is not of great moment just now as there is very little iron available for sale, output being chiefly broken up by contracts already made. Demand on both home and foreign account is unabated, consumers continuing to clamour for supplies. Most of the iron now being exported is for Belgium, but the ultimate destination of some so consigned is Holland. For home consumption, No. 1 Cleveland pig-iron is 182*s.* 6*d.* and No. 3 and the lower grades are 175*s.*; and for shipment to France, Belgium and Italy, the former is 187*s.* 6*d.* and the latter are 180*s.* For export to other countries, the minimum quotation for Cleveland iron is 230*s.*

Hematite.—East Coast hematite is practically unpurchaseable. Makers are well sold and they are not in the market to do business at present, declaring that the cost of output does not permit of hematite being sold profitably at current rates. No. 1 is 222*s.* 6*d.* and mixed Nos. are 220*s.* for home use; and for export to France, Belgium and Italy, No. 1 is 232*s.* 6*d.* and mixed Nos. are 230*s.*

Resumption of Trade with Germany.—There are a good few inquiries for iron for Germany, and portions of some parcels sold to that country have already been despatched. Sales of Cleveland pig-iron, hematite and ferro-manganese have been made. The 200 tons of pig-iron officially reported shipped to Germany last week, however, was to be forwarded on to Switzerland. Of 2,000 tons of East Coast hematite sold to Germany, 1,250 tons have already been despatched *via* Rotterdam. A further sale of hematite to Germany has been put through this week.

Foreign Ore.—Values of foreign ore are still moving upward, and to what extent they will ascend cannot be gauged at all. Already quite alarmingly high and unprecedented figures have been touched. As the quotation for rubio, of 50 per cent. quality is 50*s.* on

the 17*s.* parity, freights Bilbao-Middlesbrough, and as the latest fixture for that trip is 37*s.* 6*d.*, the c.i.f. Tees price of best rubio may now be put at 70*s.* 6*d.* Tonnage is difficult to secure and imports of ore so far this month are considerably below those for the corresponding period in January.

Coke.—Great firmness characterises coke. Supply is scarce, and indeed the situation is so unsatisfactory that there is a growing feeling in favour of restricting exports with a view to dealing more efficiently with pressing home needs. Foreign demand is heavy, but sales are not easily arranged. It is difficult to ascertain what some countries will pay, but, generally, the export figure for both foundry and gas-house coke may be put at 120*s.* f.o.b. To home customers average blast-furnace description is fully 50*s.* 6*d.* at the ovens; and low phosphorus quality readily realises 53*s.* at the ovens.

Manufactured Iron and Steel.—It is almost impossible to place orders for manufactured iron and steel, so fully occupied are producers. Buyers are very anxious to make contracts, the 20*s.* rise in steel having had no check upon them. Many purchasers, in fact, would not hesitate to pay even above the high rates ruling, for anything like early delivery. Export prices are above the recognised market quotations for home trade, which are governed by the following:—Common iron bars, 24*l.*; marked bars, 26*l.*; steel ship, bridge and tank plates, 21*l.*; steel boiler plates, 24*l.*; steel angles, 20*l.* 10*s.*; steel joists, 20*l.* 10*s.*; steel strip, 27*l.* 10*s.*; steel hoops, 27*l.* 10*s.*; soft steel billets, 19*l.* 10*s.*; hard billets, 20*l.* 10*s.*; heavy sections of steel rails, 19*l.* 15*s.*; and fish plates and sleepers, 24*l.* 15*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

State of Trade.—Great activity continues in the general trade of the West of Scotland and all the engineering and allied trades are exceptionally busy. Much difficulty is still being experienced in securing the necessary supplies of both raw and manufactured material in order to keep plants running. Prices of everything continue to advance, and what the quotations of the morrow will be it is always difficult to forecast, but, nevertheless, prices matter less than deliveries, which are backward and cannot be relied upon. Speeding-up has taken place in a number of establishments, but the output over all is far from what it might be. Labour has been fairly settled so far this year, but in a number of trades there is again a demand for further increases in wages. In the shipbuilding and engineering trades there is to be an application put forward shortly for an advance of 15*s.* per week, and if that demand is pressed there is no saying what the result may be. Wages have already reached an unprecedented level, and still the end seems not yet. Certainly "the labourer is worthy of his hire," and every man wants to sell his labour in the best market, but if output does not increase considerably and production is not speeded-up there is a danger that the consequences may be serious.

Scotch Steel Trade.—In the Scotch steel trade there has been little change over the week, and it is still the old story of the demand being much greater than the supply. No matter how much stuff is turned out it is as quickly absorbed as ever and still there are many kept crying for deliveries. Operations are being hindered owing to the shortage of material, and in this connection some of the Clyde shipbuilders are feeling the pinch. Plate mills are turning out a heavy tonnage, but even that falls far short of the requirements of the shipyards, in which there is much activity. For boiler plates there is also a good outlet, and the consumption of sections has improved considerably. Makers of black sheets are kept working at high pressure in the endeavour to cope with the business already booked, and are rather averse to fixing up anything fresh in the meantime. Galvanised sheets, even at the present high figure being asked, are finding a fairly good sale. The export trade continues small owing to the enormous home demand, and the lots that are going through are at quite a substantial advance on home quotations. Prices over all are very firm and the recent advance has failed to check the demand.

Malleable Iron Trade.—There is no falling-off in the demand for bar iron and all the makers in the west of Scotland are very busily employed on home orders, as consumers keep pressing for material. Deliveries are fairly good, but are far from equal to requirements. Export inquiries are again on the increase, but there is little available for shipping abroad and lots going through are at very substantial prices. All quotations are firm and unchanged.

Scotch Pig-Iron Trade.—A strong tone prevails in the Scotch pig-iron trade, and makers are as busy as they can possibly be despite the very high prices quoted. The No. 1 grades of iron are, in most cases, all sold well forward, and fresh bookings are meantime not being accepted. Prices for all makes of iron are very strong, and as all costs are rising, the outlook from the consumers' point of view is rather serious. Export business is not increasing to any extent. Hematite iron is in heavy demand by steel-makers, who are getting through a large tonnage per week. The price named for No. 1 foundry iron for shipment is round 12*l.* 10*s.* per ton.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Markets.—Export business is practically at a standstill because of heavy allocations to inland consumers. The local docks are crowded with vessels, and there is also in addition a good fleet of steamers in the roads. The authorities are keeping a very tight hand on releases, and in several instances boats have been waiting in the docks a fortnight or more for cargoes for neutral countries which they are unable to obtain because of the refusal of the authorities to release coals. Even for France and Italy it is difficult to obtain releases. Large quantities are being shipped to home ports for the purpose of bunkering, and until there is a considerable relaxation in home requirements the quantity available for shipment abroad is bound to remain short. It is reported that a considerable number of vessels have been directed from the foreign to home trade, and with loading accommodation congested vessels have to wait lengthy periods to obtain tips. Prices in the circumstances are nominal, and though collieries generally are not asking more than 110*s.* per ton for all qualities of large coal, up to 115*s.* is offered and has been accepted, while smalls are on the basis of 95*s.* for best steams. Bituminous sorts are also exceedingly scarce, with No. 2 Rhondda large worth 105*s.* and throughs 100*s.* In fact, there is little doubt that were the coals available sellers could obtain 2*s.* 6*d.* to 5*s.* above these figures. Coke and patent fuel are practically out of the market as makers are fully booked up and are unable to produce the usual quantities owing to their inability to secure sufficient supplies of coal. Foreign exports of coal last week from South Wales amounted to 419,083 tons, of which 302,534 tons were shipped from Cardiff, 47,006 tons from Newport, 34,745 tons from Swansea, and 34,798 tons from Port Talbot.

The Iron and Steel Trades.—Though there is a slight slackening in the demand for tin plates, prices have not shown any quotable alteration as makers generally are well booked up with orders. Though business has been done at 71*s.* to 72*s.* for the basis box, through second-hand holders, 70*s.* has also been done. Steel and spelter is firm and corrugated 24-in. gauge in bundles has increased another 1*l.* per ton, to 51*l.* Tin and sheet bars are firm at 29*l.* to 30*l.*, with only odd lots available.

Value of Second-Hand Steamers.—The phenomenal prices paid for second-hand steamers is illustrated in the following recent sales. In September last the Fort Shipping Company, Cardiff, purchased the steamer Loch Leven, 350 tons deadweight, for 23,000*l.*, and has now resold her to the Vimy Shipping Company, Limited, Cardiff, for 31,000*l.*, an increase of 8,000*l.*, equal to about 35 per cent. in less than six months. The steamer Fairfield was purchased by Ambrose and Angel, Cardiff, for about 75,000*l.*, in November last, and has now been resold to Morgan and Cadogan, Limited, Cardiff, for 90,000*l.* Thus in four months this vessel of 1,380 tons deadweight has appreciated 15,000*l.* in value equal to about 20 per cent.

ANGLO-SWEDISH DEVELOPMENTS FOR THE CLASSIFICATION OF SHIPS.—The recent important developments of Lloyd's Register in France and the benefits to be obtained from the establishment of a Committee of "Lloyd's Register of Shipping" sitting in Paris, have caused a lively interest to be taken in the subject in other Continental countries. Sweden has been the first to follow the example of France in this respect, and a Swedish Committee of Lloyd's Register has now been formed at Gothenburg to enable the shipowning, underwriting and shipbuilding interests of Sweden to be represented in the classification of Swedish ships. This will provide an efficient means of placing at the disposal of the shipping community in Sweden the experience and knowledge of Lloyd's Register, and will bring the society's clients in that country into close touch with the world-wide organisation, of which the Swedish Committee will now form an important part. Mr. Dan Brostrom is the chairman of the new committee, and Mr. Gunnar Carlsson, the vice-chairman. The position of shipbuilding in Sweden is such that she is practically able to build all the vessels she requires, including transatlantic liners.

HYPERSENSITISED PANCHROMATIC PLATES.—In order to make the photographic plate sensitive to all rays, not only to the blue and violet, dyes like erythrosin and pinaverdol (which sensitise to green and yellow), pinacyanol (orange and red), and dicyanin (extreme red and infra red) are added to the emulsion. The dyes may either at once be incorporated in the emulsion, or the ordinary plate may be bathed with the dye solution. The bathed plates are generally faster than the former, and the treatment may be zonal. Dicyanin, moreover, cannot be incorporated; on the other hand bathed plates have to be used soon after drying lest they "fog" chemically. It has long been known that treatment with ammonia further raises the sensitiveness of plates, though at the risk of fogging. Investigating the advantages of ammonia on behalf of the Bureau of Standards, Dr. S. M. Burka (Journal of the Franklin Institute, January, 1920) points out that by bathing commercial panchromatic plates in a solution of 25 c.c. of ethyl alcohol, 3 of strong ammonia (20 per cent.) and 75 of water for 4 minutes at 18 deg. C., followed by rapid drying, the sensitiveness to white light was increased 100 per cent. and the speed to the red increased even 400 per cent. When water alone was used (without alcohol) the speed was still more increased, but the plates had to be used as soon as dry. Plates of various manufacturers were used; Cramer plates could be worked a week after treatment, Ilford were useless after three or four days. The action of ammonia is peculiar because the dyes are basic, and there does not appear to be any chemical change of dye itself; the ammonia may continue to form a A_cNH_3Cl + dyestuff molecule.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, February 20, at 6 p.m., Annual General Meeting at the Institution, Storey's Gate, St. James's Park, S.W., the Annual Report of the Council will be presented; alterations of, and additions to, by-laws; resumed discussion on "Recent Advances in Utilisation of Water-Power," by Mr. Eric M. Bergstrom, of London, Associate Member.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.—Saturday, February 21, at 6.45 p.m., Meeting at the Education Offices, St. James'-road, Dudley. Paper on "Notes on Forging Practice," by Mr. T. W. Hand, of Sheffield (illustrated with lantern slides).

THE BRADFORD ENGINEERING SOCIETY.—Monday, February 23, at 7.45 p.m., a Lecture will be given in the Hall of the Technical College by Major S. Utting, M.I.Mech.E., A.M.I.E.E. (of London). Subject: "Induced Draught for Boiler Installations, with Special Reference to the 'Prat' System."

THE ROYAL SOCIETY OF ARTS.—Monday, February 23, at 8 p.m.: Cantor Lecture, "Recent Researches in the Cellulose Industry," by Mr. Charles Frederick Cross, B.Sc., F.R.S., F.C.S. (Lecture II). Wednesday, February 25, at 4.30 p.m.: Ordinary Meeting, "Industrial Training," by Mr. James Currie, C.M.G., Controller of the Training Department of the Ministry of Labour; late Principal of the Gordon Memorial College, Khartoum.

THE ILLUMINATING ENGINEERING SOCIETY.—Tuesday, February 24, at 8 p.m., Meeting at the House of the Royal Society of Arts, John-street, Adelphi, London. Discussion on "Lighting Conditions in Mines, with Special Reference to the Eyesight of Miners," by Dr. T. Lister Llewellyn.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, February 24, at 5.30 p.m. Papers to be submitted for discussion: "Restoration of a Cyclone-Damaged Breakwater End in Madras Harbour," and "Coastal Sand Travel near Madras Harbour," by Sir Francis Joseph Edward Spring, K.C.I.E., M.A.I., M.Inst.C.E.

THE ASSOCIATION OF ENGINEERING AND SHIPBUILDING DRAUGHTSMEN.—Thursday, February 26, at 7.30 p.m., at Engineering Lecture Theatre, Liverpool University, Professor E. W. Marchant, D.Sc., on "Wireless Telegraphy."

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, February 26, at 5 p.m. to 6.45 p.m. and 8.15 p.m. to 10 p.m., Joint Meeting with the Röntgen Society and the Electro-Therapeutic Section of the Royal Society of Medicine, at the Royal Society of Medicine, Wimpole-street, W. The following papers will be read: Mr. Reginald Morton, M.D., "On the Efficiency of High-Tension Transformers as Used for X-Ray purposes"; Major C. E. S. Phillips, O.B.E., "The Problem of Interrupted and Fluctuating Currents"; Mr. R. S. Wright, "High-Tension Transformers."

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, February 27, Informal Meeting at 7 p.m. Discussion on "The Education of the Engineer," to be opened by Mr. Frederick W. C. Dean, M.B.E., Member.

THE WIRELESS SOCIETY OF LONDON.—Friday, February 27, at 8 p.m., Meeting in the Lecture Hall of the Royal Society of Arts, when the president, Mr. Alan A. Campbell Swinton, F.R.S., will deliver his Annual Address, the subject being "Some Wireless Wonders."

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, February 27, at 39, Victoria-street, S.W. Lecturette, "Defects Found on Inspection of Boilers," by Mr. R. H. Kenyon, Member.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, February 27, at 9 p.m., a discourse will be delivered by Mr. W. B. Hardy, F.R.S. The subject is "Problems of Lubrication." Afternoon Lectures, at 3 p.m.: Tuesday, February 24, Professor Ernest Wilson, M.Inst.C.E., M.I.E.E., on "Magnetic Susceptibility" (Lecture II); Thursday, February 26, Mr. Arthur H. Smith, M.A., F.S.A., on "Illustrations of Ancient Greek and Roman Life in the British Museum" (Lecture II); Saturday, February 28, Professor Sir J. J. Thomson, O.M., LL.D., D.Sc., Pres.R.S., M.R.I., on "Positive Rays" (Lecture II).

STANDARD SPECIFICATIONS FOR RAILS AND TRAMWAY TRACK.—We have received from the secretary of the British Engineering Standards Association three new standard specifications. No. 79-1919 is concerned with special track work for tramways, and deals with adopted standards for crossings, switches, cross-overs, easement curves, &c. The pamphlet gives several pages devoted to standard nomenclature, each term being illustrated by means of a diagram. In all 48 diagrams are presented. There follow various tables showing standards adopted for crossings, lateral and equilateral switches, turn-outs, and so on, together with standards for the fishplate holes, and so on. No. 104-1919 deals with standard sections of light flat-bottom rails, ranging from 10 lb. to and including 20 lb. per yard, rising by 2 lb. Specification No. 105-1919 is concerned with light and heavy bridge type railway rails of seven standard sections, ranging between 14 lb. and 70 lb. The price of each of these pamphlets is 1*s.* net (1*s.* 2*d.* post free), and they may be obtained from the publishers, Messrs. Crosby Lockwood and Son, 7, Stationers' Hall Court, E.C. 4.

300-B.H.P. SEMI-DIESEL MARINE OIL ENGINE.

CONSTRUCTED BY MESSRS. VICKERS-PETTERS, LIMITED, ENGINEERS, IPSWICH.

(*For Description, see Page* 246.)

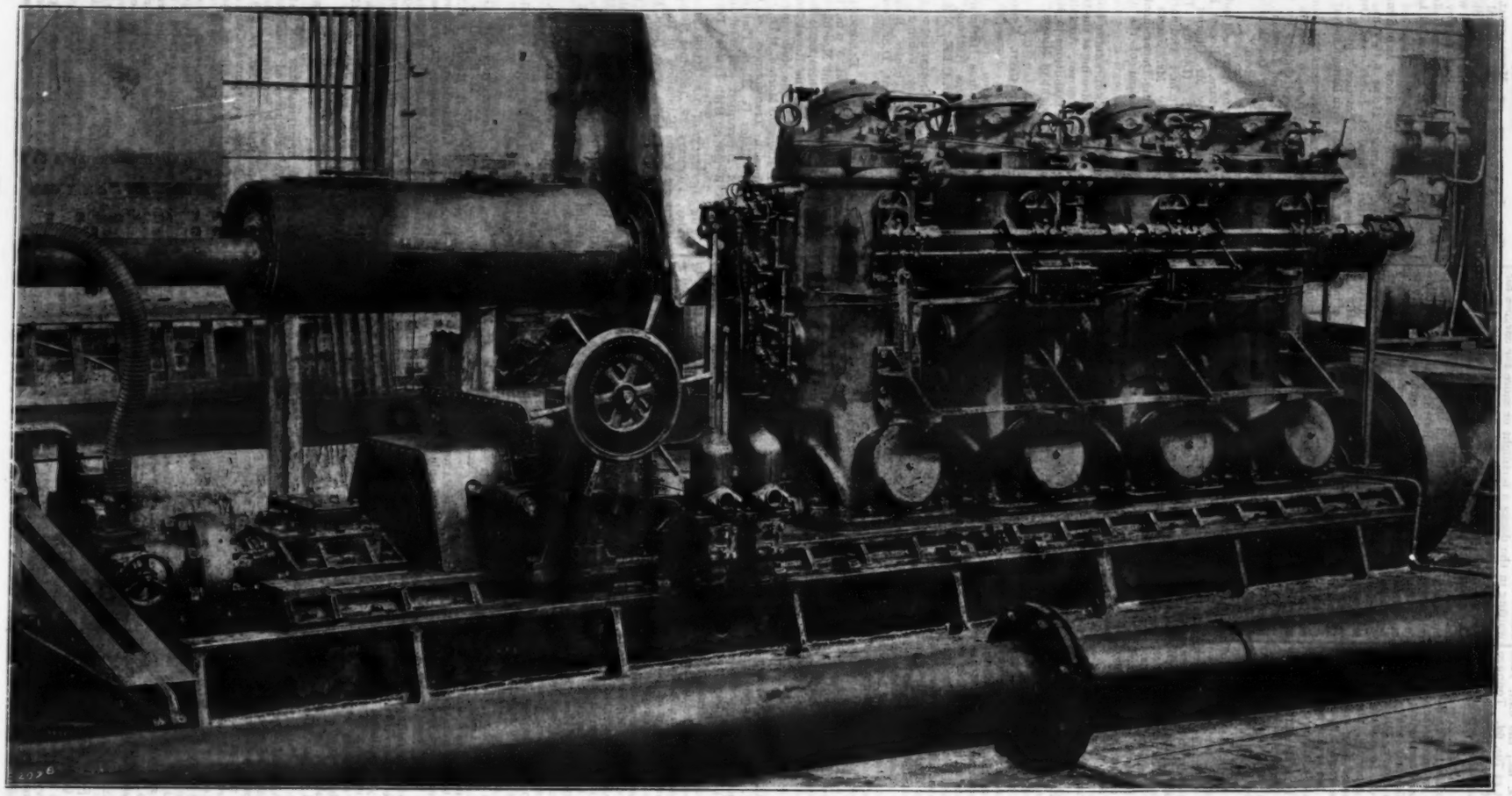


FIG. 5.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, AVIATION.—Sir Richard Glazebrook, K.C.B., F.R.S., the University of London Zaharoff Professor of Aviation, will give a course of Introductory Lectures at the Imperial College of Science on Wednesdays, at 5 p.m., commencing on February 25, on the following subjects: February 25, "Aeronautical Research" (models and full scale); March 3, "Stability and its Investigation"; March 10, "Instruments and Methods of Full Scale Research"; March 17, "Strength of Construction. Factor of Safety"; March 24, "The Airscrew—its Design and Efficiency." The lectures are free and open to persons interested, both students of the College and others. Applications for tickets of admission should be made to the Registrar of the Imperial College, South Kensington, S.W. 7.

THE PANAMA CANAL.—Two records have recently been made in connection with the working of the Panama Canal. In December last a larger number of ships used the Canal than in any previous month, while for the year ending with December 31, 1919, the traffic showed a considerable increase on any previous twelve-month. The number registered for this period amounted to 2,134, or 62 more vessels than in the previous year. The net tonnage is placed at 7,128,497, which is over 600,000 tons in excess of the previous twelve months' figures. On December 18, 1919, the Pacific Steam Navigation Company's ss. Orca, of 15,120 gross tons, took the largest single-cargo through the Canal up till that time. This cargo was figured out at 15,753 tons, weight and space measurement. The vessel was drawing 33 ft. 4 in. in salt water at the time of her passage through the Canal.

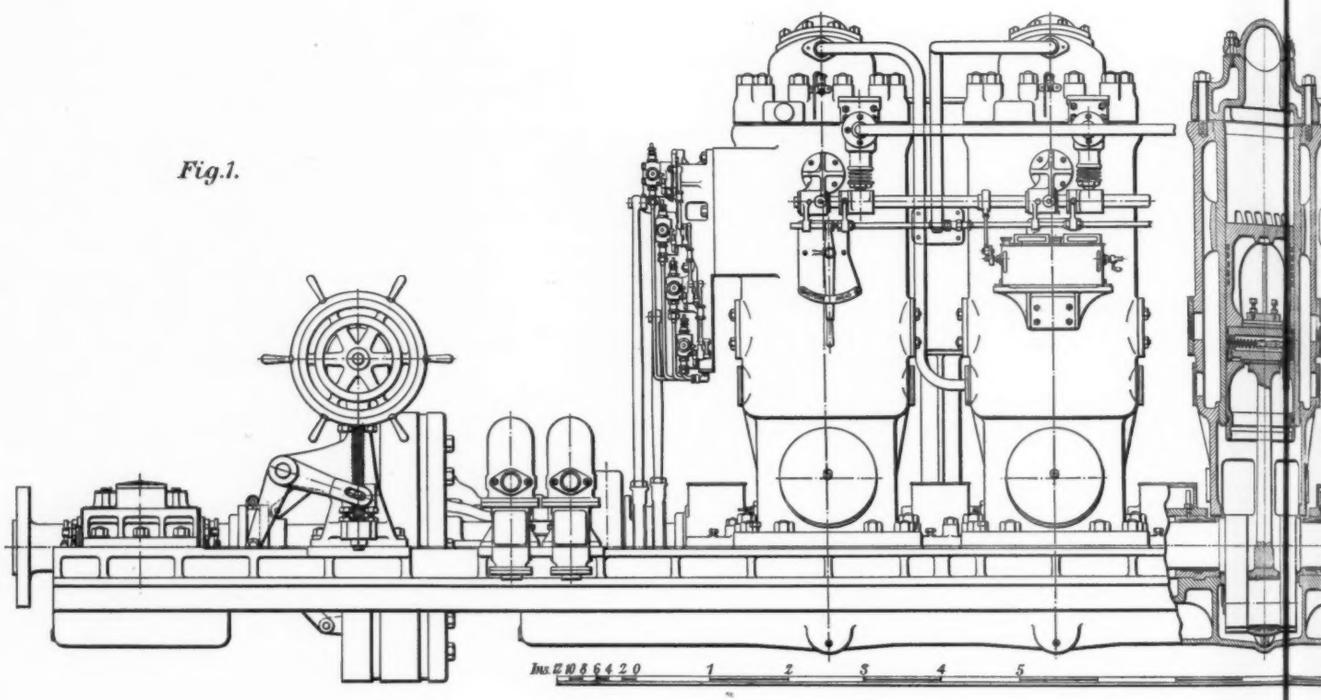
LAUNDRY AND ALLIED TRADES EXHIBITION.—The Society of Laundry Engineers and Allied Trades, Limited, has concluded arrangements for a Laundry and Allied Trades Exhibition, to be held at the Royal Agricultural Hall, from November 17 to November 24 next, the organisation and management of which have been placed in the hands of Mr. F. W. Bridges, the organiser of the recent Shipping, Engineering and Machinery Exhibition at Olympia, and many other successful trade exhibitions. The exhibition will be under the direct control of the society, who have also appointed an Exhibition Committee to co-operate with Mr. Bridges. As it is seven years since the last exhibition was held, the trade will no doubt heartily welcome the coming undertaking, which should be the means of bringing to the front the latest and most approved machinery and appliances on the market.

300-B.H.P. 4-CYLINDER SEMI-DIESEL DIRECT RE

CONSTRUCTED BY MESSRS. VICKERS-PETTER

(For Description, see

Fig. 1.



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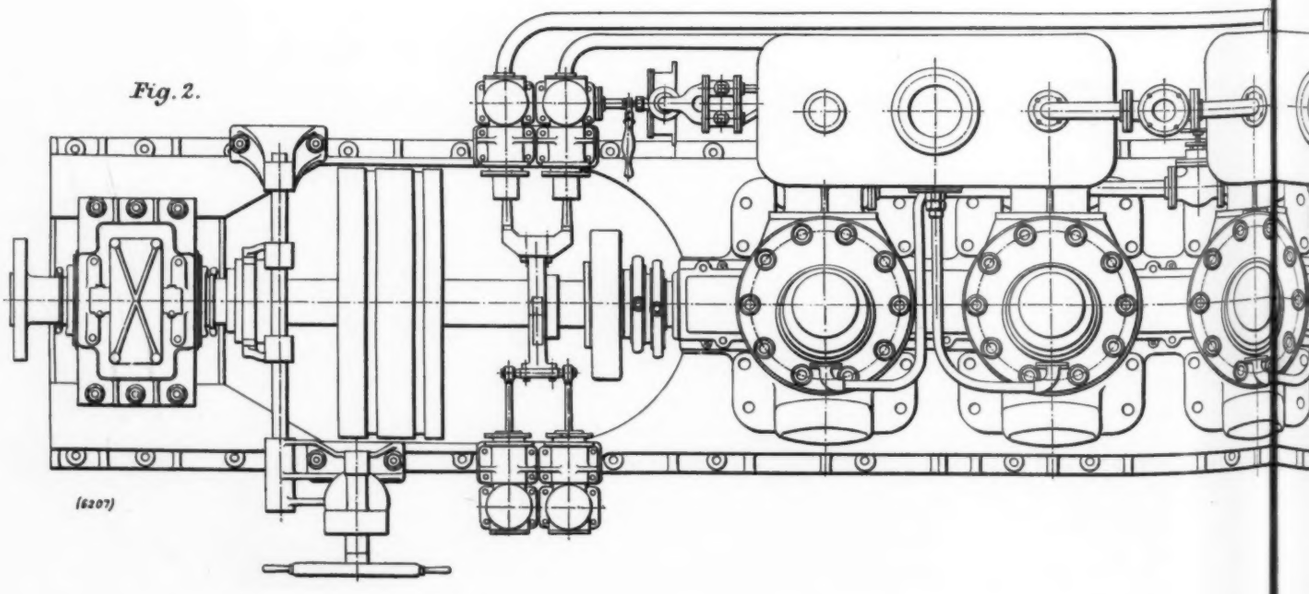

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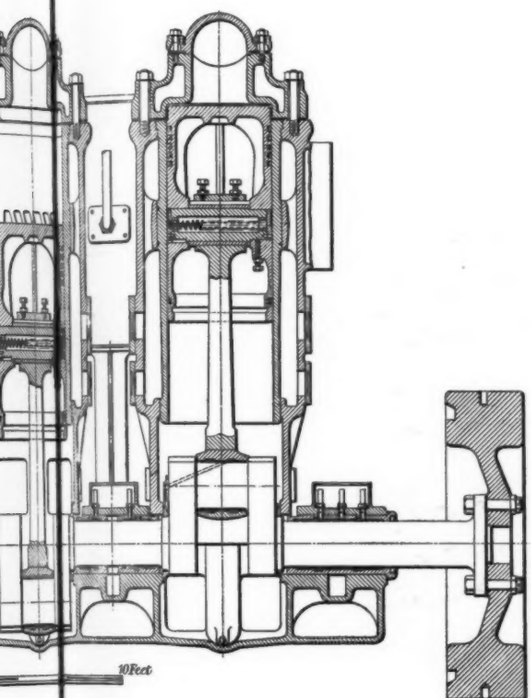
ECTREVERSING MARINE CRUDE OIL ENGINE.

KERS-PETERS, LIMITED, ENGINEERS, IPSWICH.

(Description, see Page 246.)



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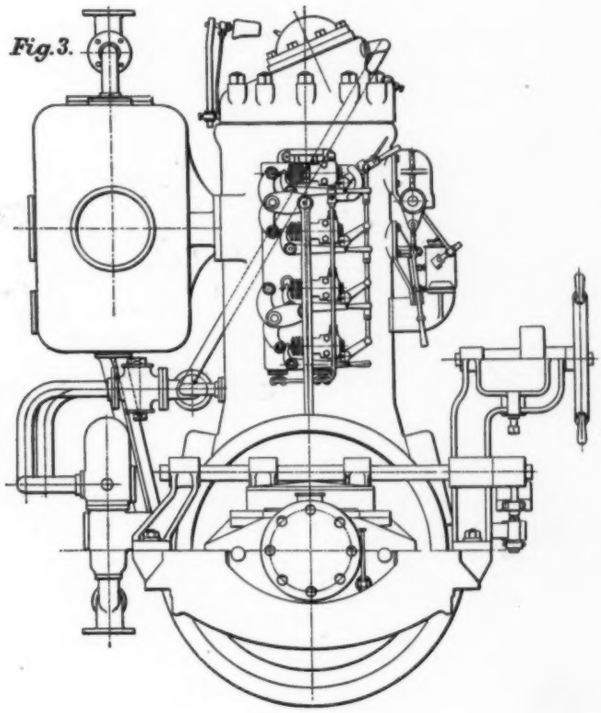

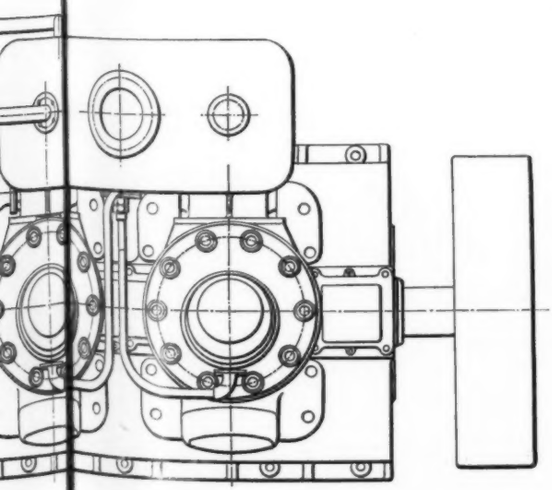

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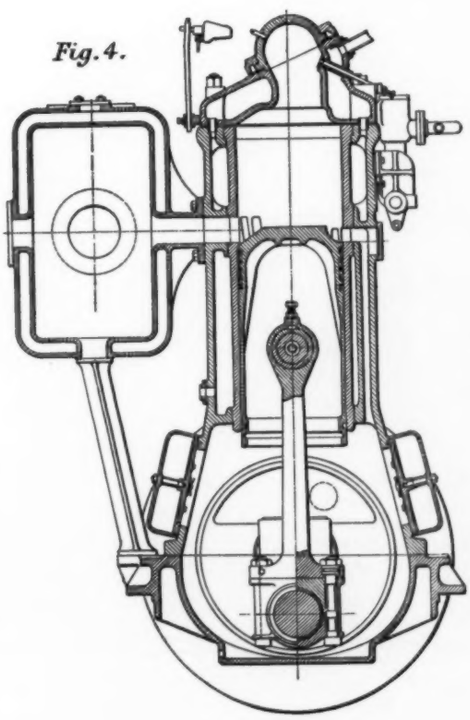

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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NOTICE.

Owing to the enormous increases in the cost of paper, engravings, and printing charges generally, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 9d. to 1s. per copy. This increase dates from and includes the issue of Friday, January 2, 1920. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 247.

ENGINEERING.

FRIDAY, FEBRUARY 20, 1920.

DIESEL ENGINE CASTINGS.

In many classes of modern engineering work, it has become general practice in design and construction, so far as steel is concerned, to take full advantage of metallurgical knowledge and of the varied and special qualities of material obtainable. The steelmaker realised that the demand for such products would be considerable, and succeeded generally in meeting the specifications of the designer, which are expressed in terms of the physical properties required to meet considerations of working stresses in practice, coupled with a reasonable factor of safety. Two convincing examples are found in the materials for automobile and aero engines. Without special steels, the motor car would be a clumsy and inefficient machine, and the aero engine almost impossibly heavy. In the case of connecting rods, bottom end bolts and crankshafts of such engines, if larger scantlings were necessary, there would be involved for a given speed of revolution, increased loads due to inertia, &c., which might well result in increased stresses. Without high tensile materials present-day speeds of revolution would generally be quite beyond the range of satisfactory and continuous performance.

The relation between composition, heat treatment, and physical properties of steels is not the subject of conjecture, or chance, but has been very completely studied in almost all its phases. It is not so with cast-iron, which is equally important, since that material forms an essential portion of most engineering structures. A great amount of experimental and laboratory research has been carried out, but the results have not to any appreciable extent been applied to practical foundry working. The moving parts of machines are not generally made of cast iron, and in many cases, where this material of ample section is used, it merely serves to give rigidity to the whole machine. On the other hand, with internal combustion engines the conditions are analogous to those which appertain to the running parts of high-speed engines, as the cast-iron parts are subject to a complexity of high stresses, owing to the heat of combustion transformed into useful work within the cylinder. These stresses must be met, and cannot be obviated by increase of dimensions of sections.

More attention is being given to this question, and a useful contribution has just been made by Mr. F. J. Cook in his "Diesel Engine Castings," reproduced on page 177 *ante*. Diesel engines being generally large internal-combustion engines, are a particularly apt subject for study in regard to suitable quality of cast-iron for the various parts. For a number of the components of Diesel engines, generally made of cast-iron, various alternatives have been tried, cast steel and manganese bronze for cylinder heads, forged steel liners, cast steel piston crowns, being cases in point; but for commercial reasons cast-iron, which is the standard material, gives satisfactory results, at least in engines of moderate powers.

In order that development towards higher powers may steadily progress and that the recurrence of unsatisfactory experiences with Diesel engine cast-iron parts may be avoided, this subject must be studied by all concerned. Mr. Cook's paper has been welcomed as a contribution of merit towards this end. The large number of factors which enter into any particular investigation of the failure of a cast-iron engine part make the collection of data a labour of some difficulty. Conclusions can only be most guardedly propounded. These factors comprise design, method of moulding, temperature of casting and rate of cooling—the two last factors being largely dependent the one upon the other—composition, arrangement of structure as revealed by microphotographs, and records available as to the treatment of the part subsequent to casting and as to actual use. Mr. Cook lays stress upon the ratio in composition of the contents of total carbon and silicon. Graphitic carbon is only mentioned in passing. A low phosphorus content is not considered so necessary when the silicon carbon ratio is within the limits specified. Some results from actual pistons taken from Diesel engines are given in proof of these theories. Without knowledge of the complete composition and of the most necessary information only to be obtained from microphotographs, it is quite impossible to say whether the cause of failure in certain cases may not have been attributable to sources quite remote from a consideration of the carbon silicon ratio. Annealing to remove casting strains is recommended by Mr. Cook. The treatment favoured is to heat the unit in a special furnace to 600 deg. C., retain the heat for 3 hours and cool slowly over a period of 48 hours. The results given by the author are not sufficiently conclusive to warrant any recommendation, and it were better not to attempt any such treatment until the improvements to be made were amply proved, and even then the control of temperature must be carefully watched. A specification for suitable cast-iron for Diesel work is given, which does not differ greatly from an average good grade of grey cast-iron. The quality, however, will be much affected, according to the rate of cooling, influencing as it does the most vital question of the closeness of the mesh work of graphitic carbon, which again has an effect on the distribution of the phosphides. A close graphitic structure of small flakes is in our opinion the most important quality for Diesel engine work, and too great stress cannot be laid upon this essential.

Much has been written lately concerning growth of cast-iron. Proof, however, is lacking that in service the castings of Diesel engines—excepting perhaps the centre of large uncooled piston crowns and exhaust valve faces and seats—are subject to such temperatures that the subject of growth is one of the more important considerations. The paper under discussion, only touches upon this aspect of the subject. Again, manganese or the ratio of manganese to silicon has a considerable influence upon the amount of growth at high temperatures, and it can be stated that high resistance to growth will mean a closeness of graphitic grain most desirable for Diesel engine work. Manganese, however, in Mr. Cook's opinion, should only be present in very small quantities. We are confident that considerable improvements will be effected as indicated in the paper, by adding a percentage of the rarer elements, such as vanadium, chrome or nickel chrome, and the like, to cast-iron. Such inclusion will serve to improve the carbon structure by forming carbides.

Much experimental work remains yet to be done, and it is to be hoped that when definite steps have been made in experimental work, they will be swiftly applied to foundry practice. Herein lies the crux of the matter. It is of no avail to make specifications if the knowledge of ways and means is not possessed by those responsible for foundry control, or if steps are not taken rigidly to enforce strict adherence to their terms. On the Continent scientific control of foundry mixtures and methods has enabled foundries rapidly to gain a very favourable position in the world's markets for castings, and as regards Diesel engine castings scientific

control of foundry methods and mixtures is an absolute essential if success is to be assured, and especially so in the case of engines developing large powers per cylinder.

THE COMMONWEALTH RAILWAYS OF AUSTRALIA.

The position of Commonwealth Railways Commissioner does not appear to be a very comfortable one, from the report recently issued of the year's working ending in June, 1919. It goes without saying that the railways are working at a loss, because some of them were badly in arrears when taken over from the State, and at the best the transcontinental line could not be expected to pay for many years. Further, recent years have not been favourable since development of the country served has been deferred. The Commissioner now points out that though the line has been opened for several years, little has been done by the States served in the way of encouraging the development of contiguous lands. As regards the Trans-Australian railway the Western Australian Government has thrown open for selection the land adjacent to the line, up to the South Australian boundary. On the other hand, the South Australian Government seems to have been very tardy in taking similar action. Through traffic has been possible since 1917, while construction was started in 1912. For a distance of 250 miles from Port Augusta, the eastern terminal, State lands have been leased, but for the remaining 350 miles up to the Western Australian border nothing has been done, although a large portion of this land is better than that actually taken up in Western Australia. The Commissioner pertinently suggests that such inaction would not have been brooked, had the line been constructed at the expense of the State instead of the Commonwealth.

Although at one time there appeared to be a possibility of the various States pulling together, and working with the Commonwealth for the good of all, there are indications in this report that the spirit of combination will stand a good deal of further development. For instance, one can imagine little more autocratic than the action of Western Australia at the time of the influenza epidemic which occurred during the year under review. The Government of this State, instead of providing the quarantine camps which its health officials considered necessary, commandeered the Commonwealth trains which entered the State, as they arrived, and treated them as quarantine stations, the arriving passengers being compelled to live in them until quarantine was raised. Trains valued at 176,000*l.* were thus diverted from their proper uses, and the train crews and other staff had to be maintained idle as a result. Very naturally, we think, this irresponsible action of the Western Australian Government resulted in the Commissioner suspending the transcontinental train service altogether for a time. It was only partly resumed after the Commonwealth had itself instituted quarantine camps, as the State Government made no sign of doing so. The service was only completely resumed after five months.

Better combination, too, appears to be desirable in connection with the through services. Before the institution of the through route from Perth to Adelaide certain trains ran from Perth to Kalgoorlie and from Adelaide to Terowie and Port Augusta, and *vice versa*, on timings which the States refused to alter. The result is that the Commonwealth service has to be made to fit these inconvenient timings. They involve a change for passengers at 4.30 a.m. at Port Augusta, and a wait of many hours at Kalgoorlie.

Then there is the question of break of gauge. Travelling from Adelaide to Perth there is first a length of 5-ft. 3-in. to Terowie, then 3-ft. 6-in. gauge to Port Augusta, then 4-ft. 8½-in. to Kalgoorlie, and then, again, a final length of 3-ft. 6-in. gauge to Perth. This journey is, therefore, full of discomfort to passengers, and transhipment at three points is involved in goods. The South Australian Government has taken steps to complete its line to Port Augusta to 5-ft. 3-in. gauge. This will cut out one change, and will make more convenient timings possible for the passenger service changing at Port Augusta. The Commissioner remarks that it would have been preferable had this railway been built 4 ft. 8½ in. Of course it would from the transcontinental point of view, but that is impossible without cutting off a large area feeding this line from direct connection with the rest of the State, as many of the branches are 5 ft. 3 in. The gauge question is, in fact, no nearer solution, and the Board which sat to consider devices intended to overcome the difficulties of break of gauge has not been able to report favourably on any of the 126 ideas advanced.

The Oodnadatta Railway, which runs north from Port Augusta, was taken over some years ago by the Commonwealth from South Australia, but is worked by the latter on behalf of the Commonwealth. It is worked at a loss. It was intended to form part of the never completed North-South transcontinental line. When taking it over the Commonwealth saddled itself with an agreement to continue to give facilities for passenger and goods traffic equal to those then in force, and at the same rates. This has had the effect of preventing any increase of rates on this line, although the South Australian railway rates have in the interim been increased. The Commonwealth Commissioner is naturally anxious to see a corresponding increase on his own line, and also asks for powers to reduce the service if trade slackens, or for other cause. The question of the completion of the North-South railway is still under consideration. Two routes are now in question. One runs practically direct north and south, while the other, by an eastward sweep could be connected up with the Queensland and New South Wales systems. The latter is only 80 miles or so longer than the former, which is not much on the total distance approaching 2,000 miles. The Commissioner puts forward what seem quite good reasons for supporting the longer route. It would pass through better country in South Australia, would run through excellent country in Queensland, and in the Northern Territory; would put Adelaide, Melbourne and Sydney into touch with excellent stock lands; would expedite the mails between the Northern Territory and New South Wales, &c.; would run through artesian country, and so on. These are all reasons worth serious consideration. It would, however, cut out the last 250 miles or so of the present Oodnadatta line, and would also run comparatively near lines projected in Queensland, so that there is something to be said on both sides.

The Northern Territory railway continues to run at a loss, and the cattle industry, which at one time promised satisfactory development, seems to be almost at a standstill and far below expectations. Other causes have led to a very unsatisfactory situation in general in the Northern Territory, which seems to be little if any better off under Commonwealth management than it was formerly. The Commonwealth further owns a line serving the Federal territory carved out of New South Wales. This is managed by and in conjunction with the New South Wales Railways.

The industrial situation was not altogether satisfactory during the year, though there was only one actual stoppage of work. The employees seem to think that they suffer disabilities in the Commonwealth service compared with the State services as there is not the same chance of getting transferred to good stations. However, the Commonwealth appears to be doing everything it can to increase the amenities of life on its system, in providing dwellings, institutes, departmental stores, and so on. A welfare officer is at work whose duties are to improve the medical arrangements, the food supplies, the management of boarding houses, the schooling arrangements of the children, and generally to place the life of the employees and their families on a higher level. An industrial officer is also proposed who should be in a position to deal with matters arising out of awards, &c., and who would be able to keep in touch with movements in the States and so bring the Commonwealth system up to the same levels.

Summarising the financial results the railways show a deficit of 141,190*l.*, excess of working expenses over revenue, and not therefore taking into account interest charges. As, however, we have already pointed out, the railways were not instituted and taken over as commercial concerns, not very much criticism can be levelled against this. With greater co-operation on the part of the States served some of this might disappear in the future. For the moment it must be admitted it shows an unpleasant tendency to expand.

GAS ADSORPTION BY CHARCOAL.

Though a good deal has been written on the use of charcoal for the adsorption of gases, it is not clear why different samples of charcoal made from the same material—generally coconut shell—differ so widely in their adsorptive power as they often do. Recent researches conducted at the Rogerson Physical Laboratory, by Harvey B. Lemon and Kathryn Blodgett (*Physical Review*, October and November, 1919), tend to confirm the opinion, however, that much depends upon a judicious heat treatment, as in the case of alloys, though the real nature of the changes produced in the charcoal by such treatment is not understood. In the experiments mentioned a number of tubular bulbs, partly charged with the charcoal (25·7 grams, *e.g.*, in a series of experiments), are joined to the same apparatus in such a way that a measured gas charge can be admitted into any of the bulbs and be expelled again subsequently under different conditions of pressure and temperature. The amount of gas admitted may either be sufficient to effect saturation of the charcoal, or be too small for that purpose; for comparative measurements the latter method is employed. Each charcoal bulb is provided with a small Geissler tube for the study of the electric discharge. In the first instance all the bulbs are together evacuated or "outgassed" by the heat of an electric furnace, the connections with the Gaede (or other pump) being left open. When the McLeod gauge no longer indicates any gas pressure, the pump is cut off, the bulb in question is cooled in liquid air, and a measured volume of dry air is admitted. The adsorption, which is controlled by pressure observations, may be very slow, taking 5 hours. Then follows the "outgassing" of the charcoal, the liberation of the gas observed, and it is this secondary outgassing at different temperatures which is observed rather than the adsorption itself.

As regards the method of carbonisation of the charcoal no information is given except that the temperature used and the period of heating are stated. Generally, we believe, the material is reduced to small pellets, which are heated in a crucible while covered with some loose refractory material. In the first series of experiments three samples of the same material were carbonised at temperatures of 900 deg., 850 deg. and 800 deg. C., respectively, and then outgassed at 425 deg. The gas pressure of 90 cm. initially was reduced, in 10 minutes, to 20 cm., 0·071 cm. and 0·003 cm., and similar results, showing wide discrepancies in the adsorptive capacity, were obtained in other experiments. In a second series carbonisation was at 850 deg., outgassing at 600 deg. for 4½ hours, and the same sample was submitted to 10 runs, *i.e.*, cooling in liquid air, adsorption and outgassing at 600 deg.; these consecutive treatments improved the sample, or activated it, giving it finally quite the efficiency of the sample that had been carbonised at the lower temperature of 800 deg. In another case, again, 10 and 12 outgassings at 600 deg. similarly improved the sample carbonised at 875 deg. On the other hand, heating of any sample to 1,200 deg. spoiled it completely, and some curious, though scarcely surprising, observations were made in this connection. The bulbs containing the charcoal were made of pyrex glass, quartz or iron. For the 1,200 deg. test, which was applied after the nineteenth run, a quartz bulb was used, and the quartz, though apparently unchanged while hot and cherry-red, turned opaque and brown as it cooled, and proved finally brittle like an eggshell, though it did not leak. The experimenters had not assumed that the quartz would not bear a temperature of 1,200 deg. in the presence of carbon. In further experiments the outgassing temperature was raised to 800deg. and higher; the charcoal distinctly deteriorated, and it lost almost all its adsorptive power by outgassing at 900 deg.; yet the efficiency could be restored by subsequent outgassings at lower temperatures. But exposure to temperatures

of 1,200 deg. (in iron bulbs) spoiled the charcoal hopelessly.

The best results were obtained by carbonising the material at 670 deg., and alternately adsorbing 0·00469 gramme of air per gramme of charcoal at — 188 deg. and outgassing for 4¼ hours at 600 deg.

As regards the nature of the adsorption various suggestions have been made. The amorphous carbon may be the adsorbent, and the charcoal may lose its activity when transformed into crystalline graphite. Some investigators believe that the charcoal contains heavy hydrocarbons clogging its pores, and that these hydrocarbons are gradually removed by the repeated outgassings. Lemon and H. C. Thompson regard the active charcoal as if it were a saturated solution of carbon in an essentially liquefied gas, and suggest that in their repeated adsorptions and liberations of gas the dissolved and reprecipitated particles become finer and finer. They boiled charcoal with mixtures of ligroin, acetone and alcohol in a reflux condenser for hours, thus extracting some of the constituents of the charcoal. The so-treated charcoal was found to be a poorer adsorbent than it had been, but it improved on repeated outgassings. Extraction of mineral ash from the charcoal by hydrochloric acid is not advisable, as the traces of acid remaining in the charcoal are very difficult to remove.

The further studies of Lemon and Blodgett concerning the selective adsorption of gases by charcoal have not gone far. In general, it has been said, the more easily-condensed gases are more abundantly adsorbed by charcoal and more persistently retained than less-condensable gases. But hydrogen is far more readily adsorbed than one would expect from its very low boiling-point. For mixtures of oxygen and nitrogen the rule seems to hold, however. Sir James Dewar briefly referred to the preferential adsorption of oxygen from air in his Royal Institution discourse of last January* ; that this adsorption might technically be utilised for the oxygen extraction from the atmosphere he had proposed years ago. The particular object of Lemon and Blodgett was to ascertain whether the adsorption increased continuously from that for pure nitrogen to that for pure oxygen as the oxygen percentage in the mixture was continuously increased. Their oxygen and nitrogen were chemically prepared and very carefully purified, and they studied the adsorption both of the single gases and of their mixtures. They found that the rates of adsorptions varied as they expected, but according to an exponential rather than to a linear law, and they are not inclined to agree with F. Bergter's suggestion of 1912 that the ability of charcoal for adsorbing nitrogen is increased by the presence of oxygen. They did not work under the same conditions as Bergter, however, and did not express any definite opinion, therefore ; but they observed that the adsorption of a mixture of the two gases was inferior to the sum of the adsorptions of the two components, and they hence assume that each gas hinders the adsorption of the other. One further observation is of interest. When the charcoal was first exposed to oxygen and then to nitrogen, the total adsorption was more complete than when the charcoal was exposed to the same amount of a mixture of the two gases in equal proportions, all at one time.

RECENT PATENTS ON MIXED FUELS.

During the year 1919 the United States alone are credited with having produced 1,900,000 road-motor vehicles driven by liquid-fuel engines ; the total production of the world was hardly less than 2,500,000. Allowing each vehicle an average fuel supply of 400 gallons per annum, some 15,000,000 tons of crude oil were probably wanted for road-motor propulsion. The total production of crude-oil had risen from 50,000,000 tons in 1912 to 75,000,000 tons in 1919, and now represents in weight more than one quarter of the British coal production. The claims of agriculture are nowhere disregarded at present, and the farmers' demand for motor vehicles will increase. How is the demand to be met ?

The problem is by no means new ; the general public is interested, and progress has been made. The prejudice against alcohol and other petrol substitutes has been overcome ; power alcohol enjoys official patronage. But owing to its low thermal value and its low vapour pressure alcohol is not an ideal automobile fuel, and as long as the volatile hydrocarbons known as petrol were readily available there was little necessity in this country to encourage the use of either alcohol alone or of mixtures of alcohol with other material. Yet to judge by the patent office records alcohol in some form or other is universally assumed to be a constituent of the motor fuel of the future. In his paper on "Recent Patents on Mixed Fuels," read before the Institution of Petroleum Technologists last Tuesday, February 17, Dr. W. R. Ormandy restricted himself to British patents for two reasons, because the field was sufficiently wide, and because he wished to do something towards preventing the Patent Office from further granting patents on the admixture of every conceivable burnable organic liquid which might possibly be used as a motor fuel, patents which would form the seeds for future patent litigation.

The new patent regulations require the opponents of a patent to point to some publication or some technical paper or document, and Dr. Ormandy had prepared his paper with the object of supplying such a document. He quoted the patents by numbers, not by names. The meeting certainly agreed with him that much of the patent literature since 1913—time had not allowed Dr. Ormandy to extend the present search further back—is barren and some positively puerile. Many of the proposals he mentioned read like recipes from cookery books ; others, like the addition of amyl acetate (of fruity smell) to petrol, look like attempts at evading the petrol tax. Although it was known by 1870 that ordinary, *i.e.*, ethyl, alcohol, will mix with paraffin hydrocarbons, provided water be absent, and that the vapours will burn in engines, the mixing of anhydrous alcohol and petrol was patented in 1913. Other inventors got over the water difficulty by stipulating that the alcoholic mixture, prepared by the fermentation of peat with kerosene, should contain fusel oil (amyl alcohol), or they recommended the addition of various combining agents. To raise the vapour pressure of ethyl alcohol, ether was added. In the Natalite,* which is used extensively in South Africa, India, Australia, Papua, and in other sugar-growing countries, alcohol and ether are mixed in about equal proportions, and half per cent. of ammonia or of trimethylamine (from the sugar) are further added to mitigate corrosion.

As regards the admixture of gases, Dr. Ormandy could quote some wild suggestions—hydrogenerations of already saturated hydrocarbons with acetylene by bubbling or by compressing the acetylene at 12 atmospheres, &c. That an extraordinarily wide range of chemicals can, if necessary, be used in internal combustion engines Dr. Ormandy had recently again learnt in Berlin, where special winter and summer fuels had to be introduced during the war. The difficulty is to find the raw material for alcohol. Cellulose is not easily converted into sugar and alcohol, and sugar is too valuable ; but the Ford works are said to have been successful quite recently with sawdust and straw. Yet Dr. Ormandy was amply justified in lodging a protest against the further issue of patents on mixtures of petrol with benzol, alcohols, ether, acetone, &c., mixtures tried over and over again with the aid of carburettors and preheaters, and against interfering with the legitimate development of a big industry.

NOTES.

FORTHCOMING AGRICULTURAL TRACTOR TRIALS.

Builders of agricultural tractors and motor ploughs will probably be relieved by the decision of the Royal Agricultural Society and the Society of Motor Manufacturers and Traders to hold a joint series of trials this year. It was always the intention of the Motor Manufacturers and Traders to make their tractor trials an annual affair, and the successful meeting of September last at Lincoln would in due course have been followed by a meeting this year. At the same time, however, the Royal Agricultural Society trials were due for next autumn. These circumstances would in the ordinary course have led to two sets of trials with consequent considerable extra expense and trouble to many manufacturers, and the possibility that neither set of trials would be fully representative. The decision to merge the two events into one is cause for satisfaction, and a very successful meeting may now be anticipated. The joint trials will be held in September and October next, but the site has not yet been determined. The trials will be competitive in accordance with the practice of the Royal Agricultural Society, and prizes and medals will be given in the various classes. The trials will cover both self-propelled and wire-rope haulage ploughing and, in addition, cultivating, hill climbing and road haulage tests.

THE MANCHESTER SHIP CANAL.

The report of the directors of the Manchester Ship Canal for the year ending December 31, 1919, shows an improvement both in tonnage and receipts over the previous year. The total traffic making use of the canal amounted to 3,589,043 tons, compared with 3,497,995 tons in 1918. The record year as regards tonnage was 1913, when the figures showed traffic amounting to 5,780,161 tons. The present tonnage is therefore still down by a considerable amount. The total receipts are, however, the highest yet reached, and amounted last year to 1,023,361*l.*, being the first time the 1,000,000 mark had been passed. Although tonnage reached a maximum in 1913, the receipts have shown a steady improvement ever since 1908. If the exceptional year of 1907 be excluded, a steady progress is marked in receipts ever since 1894. After allowing 10,000*l.* for contingencies and repairs there is a net balance for the year of 320,100*l.*, which the directors propose should be distributed with the exception of 18,568*l.* to be carried forward. No changes were made in canal rates and charges during the year. Increased expenditure is recorded in all departments as a result of increased wages, shorter hours and higher prices of materials. The general work of repairs and renewals, although picking up by degrees, is still somewhat behindhand, owing to the reduction in hours, and scarcity of materials. The capital expenditure for the year was 83,017*l.* offset, however, by sales of land, &c., to the amount of 69,136*l.*, making the net outlay 13,881*l.* The extension of the company's warehouses at Trafford Wharf is said to be well advanced. Contracts have also been let for work at Stanlow, near Ellesmere Port, including a new dock, and subway under the ship canal.

LANCASHIRE ENGINEERING SOCIETIES.

The amount of engineering manufacture which is carried on in London is very considerable, and is more perhaps than is always realised in some of the more definite engineering centres of the provinces. None the less, London is not in any broad sense an engineers' town, and the great engineering institutions suffer in some ways from the fact that their headquarters are necessarily situated there. A discussion in the London house of one of the great engineering societies is apt to be looked upon as a full-dress debate and to be left in the hands of more prominent members of the profession. With a view to encouraging contribution by younger or less prominent engineers both the Electrical and Mechanical Engineers have recently inaugurated informal meetings as additions to their programmes. A distinction between the London and the provincial societies is indicated by this movement, and we think any similar arrangement would be much less necessary in, say, Manchester or Liverpool. In addition to the somewhat more free atmosphere of a provincial meeting with consequent encouragement of more general discussion, the provincial societies have a valuable sphere in giving attention to questions particularly affecting the district for which they stand. Thus, as might be expected, the proceedings of the Liverpool Engineering Society will be found to contain much material relating to marine practice, while those of the Manchester Association of Engineers deal to a considerable extent with problems of manufacture. That both these Institutions are in a state of very healthy life was indicated by the success of their annual dinners,

* See ENGINEERING, January 23, pages 122 and 123.

* See page 150 *ante*.

which were held respectively on the 12th and 13th inst. At Liverpool, some 245 members and guests assembled under the chairmanship of the president of the Liverpool Engineering Society, Mr. J. Hamilton Gibson, and in Manchester some 226, the chair being taken by Mr. Harold F. Massey, the president of the Manchester Association. A number of prominent engineers were among the guests, and speeches on both occasions were delivered by Lord Weir and Engineer Vice-Admiral Sir George Goodwin.

British Technical Societies.

The balance sheets of a large number of technical societies throughout the United Kingdom have for some time past shown a balance on the wrong side, the reason for this being the increased expenditure in practically all counts. The cost of the "Proceedings," in the case of many Institutions, forms the most important item in the higher expenditure, and this is not surprising, considering the very high and constantly rising prices paid for paper, printing, engraving and binding. Some technical societies find that the only way to meet the situation is to increase the amount of subscription paid annually, by the members, a very rational means, in fact the only means, since the members' subscriptions form practically the societies' only source of revenue. But in the case of some associations it happens, owing to the Charter or articles controlling the action of the societies, that before this comes into operation and yields its full effect, one whole year must elapse. In the meantime, the members are, in the case of some societies in which these conditions exist, invited to increase voluntarily their subscriptions for the current year. This move is greatly to be commended, and it is hoped that it will be generously responded to. It is hoped, also, that when the resolutions of the councils to increase the members' subscriptions come forward at the forthcoming meetings of the different technical societies, these resolutions will be passed by large majorities. In no instance, we believe, is the situation in any way a bad one; the question at issue is the free progress in the future, as in the past, of our technical societies, and these in their different spheres have done so much excellent work to promote the development of science, knowledge and friendly intercourse between members that they deserve all the support the members are able to give them. A delicate item in this connection, however, is the following. Many of the British technical societies have on their rolls a comparatively large number of foreign members who belong to the Continental allied nations, and owing to the unfavourable rate of exchange now ruling, and likely to continue for some time to come, these members have practically to pay 2*l.* for every 1*l.* they remit to this country. The whole matter is one which is, as it were, *sub judice* with the councils of the various societies, and we do not wish to appear desirous of influencing any general decision; but it certainly seems that the point just raised deserves full and generous consideration. Indeed, the councils have no doubt forestalled us in considering in that light the case of the foreign members we refer to. British members will no doubt also have borne this point in mind when voluntarily increasing their subscription for the current year.

English Canals.

It is quite true, as Mr. S. Preston remarked in his paper on "English Canals and Inland Waterways," read before the Royal Society of Arts on Wednesday last, that it is extremely difficult to find anything to say on the subject that has not been already said time after time. Although an interesting survey of the historical aspect of the subject, and of its present position, it cannot be said that it takes the subject much further. Canals are up against the fact that at the present time they have little prospect of being made to pay. It is true that during the war they performed useful duty, and relieved the railways of certain heavy traffic, which might without loss to the trading community continue to use this form of transport, but only at a cost to the nation which it is very difficult to appraise at anything commensurate with the service rendered. It is true that the picture of prosperous waterways and steamers alongside wharves in our inland towns is an extremely attractive one, but with such small cross-country journeys to the ports, and such an extensive coast line, to say nothing of unfavourable physical features inland, the problem of salving our canals cannot be compared with such questions in France or other countries. The difficulties of arriving at workable propositions is evidenced by the amount of abortive work put in on these questions by many committees and commissions of the past. All these efforts have resulted in nothing. To-day the position is complicated by the Ministry of Transport Act. Although this would seem superficially to simplify things it rather adds to their complexity. For instance, as Mr. Neville Chamberlain remarked at Wednesday's meeting, although the Minister of Transport would control the canals for two years there was the vital question of ultimate ownership to be decided before much could be spent on renovation. And, if the Minister decided on larger improvements, who was to be allowed to benefit from them? Was it to be only a small body of manufacturers near to the canals? It is essential for action to be taken at all that the Government policy should be announced as early as possible. With this we quite agree, and it will be well for many things if it proves ultimately that the programme is to be a restricted one. There are possibly some waterways which might be made to pay, but with the present and future financial burdens coupled with the greatly increased operating expenses and delays in working, due to the 48-hours' week and no night working on the boats, the sooner most of our canals are definitely abandoned and other forms of transport developed to take their place in the nation's internal economy, the better it will be for the taxpayers, who form so large a part of the community.

The Regina Turbine Disaster.

Information has now come to hand which enables us to give certain interesting particulars concerning the wreck of the 5,000 kw. Curtis steam turbine in the municipal power station of the City of Regina, in Canada. The machine, which was only put into service last autumn, had a normal speed of 3,600 r.p.m., and was direct-coupled to a three-phase, 60-cycle alternator. The turbine was of the five-stage type, the first stage being velocity compounded, and the rest being single-impulse stages, thus following the usual modern Curtis practice. The mean diameters of the wheels measured at the centre of the blades, were, we are informed, 38 in., 50 in., 50·5 in., 51 in. and 52 in., respectively, the mean blade speeds thus ranging from 565 ft. per second on the first wheel to 816 ft. per second on the last wheel. The turbine was guaranteed to have a full load consumption not exceeding 13·68 lb. of steam per kilowatt-hour, when operating with steam at 200 lb. gauge pressure superheated 100 deg. F. and exhausting against an absolute condenser pressure equal to 2 in. of mercury. The designed efficiency ratio was therefore 69·2 per cent. It is believed that the disaster was caused by the bursting of one of the turbine wheels, but the whole machine is so utterly destroyed that the true cause may never be definitely ascertained. Nothing was left of the turbine beyond debris scattered around the engine-room, except that the valve chest remained attached to the steam pipe which was forced very considerably away from its original position. The machine burst at 7 a.m. on January 8, and could only have been carrying a light load at the time. In fact, it is doubtful whether it had ever been called on to work at its rated capacity, for the winter peak of the station is only about 4,000 kw. One of the engineers was standing at the steam end of the machine when the burst occurred, and he had the almost incredible good fortune to escape with little more damage than a scratch on the nose and the loss of some hair. Similar good luck attended the other units in the power-house, as the broken turbine shaft with the remains of its wheels flew through the air and landed 20 ft. away between two Willans turbines, neither of which received injury worth mentioning. The General Electric Company of America, in consequence of several serious mishaps in connection with steam turbines, are stated to have dismantled and rebuilt this particular machine before delivery in order to eliminate any possible source of weakness, but unfortunately the precaution proved in vain. The sympathy of all central station engineers will be extended to Mr. E. W. Bull, the engineer and manager of the Regina Station, at the calamity which has befallen his power-house, the high efficiency of which has previously been the subject of comment in our columns.

Overseas Touring Exhibition.

There is without doubt no time like the present for trade opportunities abroad, if our firms will only stretch out their hands and lay hold on them. If we concentrate too much on home requirements and on temporary foreign markets we run the risk of ultimately finding, when we turn to them, possible permanent markets abroad already occupied by others. It is to be hoped therefore that support will be given by our manufacturers to the proposed overseas touring exhibitions which are being organised as a development of the British Industries Fairs, which have proved so successful, and which have undergone such striking development in the few years of their existence. Four tours are at present proposed, the first to the Dominions; then one to South America, one to the Far East, and one to the United States of America. The arrangements for the first appear to be well advanced, the date for leaving England being fixed for the early part of June. This tour will include South Africa, the Australasian Colonies, British Columbia, Canada, &c. It is expected that two years will be occupied by the tour. Facilities will be of a kind suitable for the exhibition of a large variety of goods, including, among those of particular interest to our readers, cutlery, scientific instruments, optical goods, tools (hand), implements (agricultural, &c.), and so on. The exhibition should prove self-supporting on the basis of 500 exhibitors each taking up a 10-ft. frontage at a charge of 200*l.* Half units, or 5-ft. frontages, will also be available. It may be pointed out that this is an exceedingly small cost to a manufacturer for the opportunity of displaying his goods for altogether about 224 show days in 16 centres as far apart, for instance, as Johannesburg, Melbourne, Vancouver, Halifax, &c., to mention only a few of the arranged exhibitions. Firms will be able to send representatives, though this will have to be arranged for by them. It is suggested that several firms might co-operate in this matter, to the extent of having joint representatives, and even joint exhibits. Further information may be obtained from the Secretary, Dominions Touring Exhibition, Department of Overseas Trade, Exhibitions Division, 2, Queen Anne's Gate Buildings, S.W. 1. Applications for space must be sent in before March 31. It is to be hoped that our manufacturers will cordially support this venture, which may result in reviving a good deal of our trade abroad. The only weak point in the scheme appears to be in the fact that goods suitable for, say, the Durban market will not necessarily do for Halifax, and *vice versa*. Instead of all the exhibits therefore being of interest to people at the points visited, the cases will have to contain a variety only part of which may be of interest at any particular centre. However, this does not apply to all goods, and even in the least favourable cases the results may well prove of considerable future value.

Durability of Aeroplanes.

In many respects the design of aeroplanes for commercial use differs materially from that of the war machines in which our designers have gained most of their experience. For the former, the question of durability is one of considerable importance, whereas, in the latter, it received little or no attention for the simple reason that the life of a machine under service conditions was usually determined by other conditions than structural durability. The advent of a new and improved design, in many cases, rendered existing machines obsolete almost as soon as they were constructed, and in any case the conditions under which the machines were employed were such that they were rarely worn out with use. In commercial service, on the other hand, the rate of deterioration of the machines is of the utmost importance, so much so

that the success or failure of a scheme may easily turn on the question of depreciation. At present but little information as to the life of aeroplanes under commercial conditions is available, but apart from the engine, there is no very obvious reason why the life of an aeroplane should not be made at least equal to that of a motor car. All-metal construction, suitably protected against corrosion, and a more durable covering material for the wings, tail plane, elevators, &c., appear to be the main desiderata, but in addition to these there are a number of minor points in design which have, in the aggregate, a considerable effect upon durability. Some of these are touched upon in an interesting paper read before the Royal Aeronautical Society on Wednesday last by Major Percy Bishop, who points out that machines deteriorate more rapidly on the ground than in the air. Much of the deterioration is, of course, due to atmospheric conditions, especially in the case of seaplanes. To ameliorate it attention must be given to the selection of suitable materials and to their protection, as far as possible, from direct contact with the air. Drainage arrangements and the general avoidance of pockets where moisture can collect must also be considered in the design. A point to which Major Bishop calls particular attention, however, is the damage caused by bad handling on the ground, and climbing about the machine in the sheds in connection with the work of filling the tanks and overhauling the parts. For this purpose he rightly states that the uses made of some of the structural members render the designer's stress calculations of little value. Axles, radius rods, exhaust pipes and struts are frequently used as working platforms, and bracing wires, fairings and similar parts are called upon to act the part of banisters. Much of the damage caused in this way could be avoided by the inclusion of suitable treads and hand holds in the design of the machine, not only for the use of persons entering the cabin or cockpit, but also giving convenient access to the parts which need to be examined and adjusted in the sheds. In connection with the filling of the tanks, Major Bishop makes a strong plea for the provision of larger and more easily accessible filling apertures in order to reduce the time required for this operation, and also to diminish the risk of damage to the machine. He also points out that, as machines are usually handled on the ground by unskilled persons, it is necessary to give precise directions for the various operations, or, better still, to provide handles in suitable position. Such handles, if properly incorporated in the original design of the machine, need add little, or nothing, to its weight or air resistance, but they would certainly tend to prevent damage by the careless handling of covered parts. Forethought in the directions indicated above appears likely to be well repaid by the resulting reduction in the present high rate of depreciation, of which so much is made by the opponents of civil aviation.

NOTES ON NEW BOOKS.

LAST week in a leading article we reviewed the question of payment by results, on which one of our leading trades unions is about to vote. The matter is of vital importance to the nation at the present time. We are most of us agreed that only by increased production in the forthcoming months can we hope to turn the corner and get well started again on financially sound lines. The difficulty is to get the workers' unions to look at things in a similar light. Most of these seem to feel that after the recent strenuous years an easier time is due to them. While admitting that we would like to see it we are convinced that for the moment it is of the greatest importance that efforts should not slacken off while the future is so uncertain. One would think that payment by results would be welcomed generally, and we believe it would be if the individual workers were free agents. As matters stand the unions have to be convinced that the method is advantageous, and this is a matter of difficulty because these bodies have often worked on the basis of reducing the good man's effort to that of the poor worker, on the plea of protecting the latter. A good many books on bonus and premium systems of payment have been written, and it is doubtful if there is much new to be said on it. We certainly cannot find much that is novel in a book recently written by Mr. J. E. Prosser, entitled "*Piece-Rate, Premium and Bonus*" (Williams and Norgate, 6s.), but the various systems are certainly concisely treated and clearly described in it. Attention is drawn to the attractive features of the several systems commonly applied, and we admit that the present situation may be a fair excuse for adding further to this class of literature.

Captain Julien, a French expert in the use of machinery in every branch of agriculture, on completing his military service with the French Army, has written a booklet, the object of which is to demonstrate the value of mechanical appliances not only to landowners in a large way of business, but also to farmers whose holdings are comparatively limited, and colonists. The booklet, which is entitled "*Manuel de Culture Mécanique*," is published at the price of 4 francs by Messrs. Hachette, 79, Boulevard St. Germain, Paris. It reviews cultivation from the first breaking of the ground and deals with ploughing on the various systems and with the final preparation of the soil. The work of the plough is criticised, and in this connection, the statement made many years ago by an eminent French agriculturist, Mathieu de Dombasle, is cited, to the effect that "the most perfect ploughing is that which is done by a spade." Hence the ideal ploughing machine would be that which would carry out spade work on a large scale. The author shows the diagram of a machine from which it is claimed such a result is obtained. It consists of a drum provided with a series of hook-shaped prongs or tines, hauled and caused to revolve at the same time by a tractor, the tines by digging into the earth producing in the rear of the machine a thick layer of light, aerated soil. A machine of this type which, alone, does the work both of a plough and of a hoe in one operation, is built by the Société d'Outillage Mécanique et d'Usinage d'Artillerie, St. Ouen, near Paris. The booklet is written as a guide for practical agriculturists. The author asks the French soldiers of every rank who left the land for the army, to return back to the land and there they will ascertain that agricultural engineering is able to prove most helpful from every point of view.

Technical reviews and journals in the Italian language afford a proof—if a proof were needed—of the prominent position occupied by the engineers, electricians, architects and naval constructors of Italy. Much is done also in Italy to propagate technical information over as wide a circle as possible, and among the publications which have made a success of this may be mentioned the Hoepli manuals, of which close upon 2,000 have now been published, dealing with every conceivable branch of industry, knowledge and science. These are real handbooks, they are edited by specialists, professors, men of science and practical engineers; they are carefully printed, illustrated and bound. An idea of their scope is afforded by a reference to three of the latest issues. One of these deals with "*Telemetry in Practice and in Theory*"; the second is a "*Practical Handbook for the Use of Reinforced Concrete*"; whilst the third is a "*Practical Guide for the Modern Mechanic.*" These publications, of course, are written for readers of Italian Nationality, but they appeal also to a wide circle of foreign readers who are students of the Italian language. Their price varies according to their size; they can be obtained from Messrs. Ulrico Hoepli, Milan.

EXPERIMENTS ON THE HORIZONTAL PRESSURE OF SAND.*

By PONSONBY MOORE CROSTHWAITE, B.A.I., M.Inst.C.E.

RECENTLY the author made a series of experiments to ascertain the angle of internal friction in sand, clay and other materials by loading a plunger of known diameter and measuring the penetration caused by known weights. The value of ϕ, the internal angle of friction, was calculated from Rankine's formula:

$$d = \frac{P}{W}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

when d is the penetration in feet, P = the pressure per square foot, W = the weight of the material per cubic foot.

The angle of internal friction from these experiments was much less than the angle of repose, and was not constant for any one material, but depended on its state of aggregation, whether it is put loosely together, shaken or consolidated by tamping.

The conclusion he arrived at was that walls calculated by Rankine's theory, which assumes the "angles of internal friction" and the "angle of repose" to be the same, would have a factor of safety of from 2¼ to 4. In order to test this conclusion, a number of experiments were made in which the pressure of dried sand against a model wall was measured. The first experiments were made with a vertical door backed with sand and hinged at its lower edge, the tension in a string necessary to keep it in position being measured. Experiments were made: (1) With the sand lightly poured into the box of which the hinged door formed one end; (2) with the sand thoroughly stirred together; (3) with the door surcharged to an angle of 30 deg., the angle of repose of the sand being 35 deg.; (4) with the door surcharged to different angles.

These experiments proved that the pressures calculated by Rankine and Colomb were much too high, especially for the surcharged wall.

At the same time experiments were made to test the wedge theory. A false bottom coated with glued-on sand, was provided that could be set at any angle with the back of the wall, so that the pressure produced by any wedge could be measured. These experiments proved that the wedge theories of Darwin, Boussinesq, Brightmore and others, that take into account the friction between the back of the wall and its backing, give correct results for the wedge of maximum thrust so long as the wall is not surcharged, but that it breaks down altogether when applied to a surcharged wall, the calculated pressures being 30 per cent. too great; also that wedges making a small angle with the back of the wall produce a greater pressure than calculation by the theory gives.

These results made the author think that something was wrong with the theory, and it occurred to him that it might not be right to take into account the friction between the wall and backing. He therefore modified the equation by which the pressures had been calculated, neglecting the friction between the wall and backing, and introduced into it an angle of internal friction instead of the angle of repose.

The angle of internal friction was arrived at by calculating what angle would satisfy the maximum pressures observed for the unsurcharged wall for the sand lightly put together and well stirred together. These angles, instead of being 35 deg., the angle of repose, were 42 deg. — 20 minutes and 40 deg. These angles were then used for calculating the undivided wedges, the results coming out in marked agreement with the experiments. The angle 42 deg. — 20 minutes was then used to calculate what should be the pressures for the surcharged wall, with the result that there was the same agreement, the maximum calculated pressure being practically identical with the observed.

The author then carried out experiments to definitely test if wall friction did actually affect the horizontal pressure or not. For this investigation new apparatus was used.

A long box was cut into two compartments by a vertical saw cut transverse to its length. One-half was fixed to solid supports, the other being carried on live rollers. When the box is full of sand the two compartments are urged asunder by the pressure of the sand on the plane passing through the saw cuts. This is the pressure on Rankine's ideal plane, and it was determined by measuring the tension on a string that prevented the rolling half of the box from being pushed forward. The rolling box was then turned end for end, so that the sand in the fixed compartment was held in position by the solid end of the box, the face of which was coated with glued-on sand. This is the same as if it had been retained by a rough wall, and if friction between the wall and backing affects the amount of the horizontal thrust the amount of the tension now required to keep the rolling box in position should have been less than before. A large number of experiments were made, and it was found that there was practically no difference, and proved, so far as laboratory can, that it is not correct to assume that friction between the wall and backing can affect the amount of the horizontal thrust.

The results of all the author's experiments prove that the angle of internal friction is considerably greater than the angle of repose, and that it varies with the state of aggregation of the material. Also that the latter is a physical constant that relates only to the surface where the particles are free to rotate, but that at the interior of the mass it is the angle of internal friction that determines the stability. It is therefore unlikely that any theory can give correct results which only takes into account the angle of repose. In Darwin's paper on the "Horizontal Thrust of Sand,"* he says that "the maximum internal friction in various parts of a mass of sand is not constant at all;" but nevertheless he uses the "angle of repose" as the "angle of internal friction," and tries to make his theory fit in with his experiments by introducing wall friction.

With regard to his apparatus used in his experiments, the author found that the wall on live rollers worked extremely well, and believes that it could be designed to measure the pressures against a wall 10 ft. high and 10 ft. wide. With such apparatus it is suggested that it would be possible to investigate clay backings, which are not likely to be amenable to treatment in such small apparatus as was used in the present experiments.

The conclusions the author would draw from his investigations are:—

1. That the plane of rupture may be a convenient mathematical fiction, but has no existence in the granular material dealt with—at least, he was unable to trace any evidence of it in his experiments.

2. That the angle of repose is a physical constant that relates only to the surface, and is represented in the interior of a mass of sand by the angle of internal friction.

3. That the angle of internal friction is not a physical characteristic constant for any one material, but varies with the state of its aggregation.

4. That friction between the back of a wall and its backing does not affect the amount of the resultant thrust.

5. That the wedge theory which takes into account wall friction and the angle of repose, though giving correct results when applied to a wall without surcharge, or with a negative surcharge, breaks down completely when applied to a surcharged wall.

6. That the wedge theory when modified by leaving

* Abstract of a paper read before the Institution of Civil Engineers, on Tuesday, February 10, 1920.

* Min. Proc. Inst.C.E., vol. lxxi, Part 1.

out wall friction and introducing, instead of the angle of repose, the angle of internal friction gives correct results in all cases, whether for the maximum thrust or that produced by individual wedges.

Finally the author draws attention to agreement of his experimental results with the conclusions of Sir Benjamin Baker, who states from his experience that to retain loose earth, walls designed to withstand liquid pressures of 10 lb. to 20 lb. per cubic foot are sufficiently strong. The author's measured pressures for loose earth correspond to a liquid pressure of 18·4 lb. per cubic foot, and for well-stirred sand 14 lb. per cubic foot. The former is probably as great as would be produced by loose earth, and the latter considerably greater than that due to damp earth or sand. This coincidence is remarkable, considering the extremely small scale of the author's experiments, and that Sir Benjamin Baker's conclusions are drawn from consideration of works of the largest size.

In conclusion, the author records the assistance he received from Dr. A. W. Brightmore, M.Inst.C.E., who gave him valuable advice whilst he was carrying out the experiments, and devoted a great deal of time to making somewhat tedious and difficult mathematical investigations, without which the paper could not have been placed before the Institution.

OVERTURNING MOMENT ON RETAINING WALLS.*

By Angus Robertson Fulton, D.Sc., Assoc.M.Inst.C.E.

Experimental methods of investigating the pressure of earth on retaining walls have usually followed one or other of two directions in the attempt to decide between the claims of two main theories—the theory of prism of maximum pressure and Rankine's theory of conjugate pressures.

The aim of these methods was either to obtain the ratio of the conjugate pressures directly or deductively by experiments, or to determine the overturning moment on the wall. In the latter case indirect means, such as the stability or failure of the wall, were used, or direct measurements were made. In the present investigation the method of direct measurement of the overturning moment was employed.

The filling was of three kinds :—

(*a*) Clean river sand,
(*b*) Gravel,
(*c*) Garden soil,

and the values of the coefficient of friction and the angle of repose for each class of material were first determined.

A description and illustrations of the apparatus used, which was along the lines of the rotating board, were given. The method of measuring the magnitude of the resultant moment of the earth pressure was by observing the extension of a bar fitted with a Ewing extensometer. The movement of the material and therefore all "arching" effect was consequently reduced to a minimum.

The rotating board and apparatus were so arranged that the conditions could be made to approximate to the cases of a wall with its inner face vertical or battered inward or outward.

The operation of filling was carried out on a system described, and measurements of the moment were made with the materials at various heights, and also with and without a surcharge loading. The total height without surcharge was limited to 7 ft., and with surcharge it reached 9 ft.

An indication is given briefly of the foundations on which the theories are based, and the methods by which the general formulas derived from them have been evolved.

It is also shown in what respects the Rankine and wedge theories agree and differ, and reference is made to the direction of the resultant pressure.

The values of the overturning moment for the case of a vertical wall with no surcharge, as obtained experimentally, and those calculated from the derived formulas, are given in a table and illustrated by curves. The Rankine figures where the direction of the resultant pressure is taken as parallel to the surface of the filling are greatly in excess of the observed values, while those obtained from the wedge theory approximate fairly closely to experiment.

For inclined positions of the rotating board representing walls battered inwards and outwards, the experimental and calculated values are tabulated in other tables, and are also illustrated by curves. These indicate that calculations based on the wedge theory give results in accordance with experiment at the lower levels and in fair agreement at the higher. With the wall inclined inward the Rankine figures are about 50 per cent. in excess, but owing to the fact that they vary very little in the three positions taken, they agree more closely, though still in excess, when the wall is inclined outward.

Coming to the case of surcharged walls, it is pointed out that the equations founded on the theories mentioned apply only to unlimited planes of surcharge, and as it was necessary to limit the height to which the filling was carried in the experiments as in ordinary practice, a modification of the wedge formula was made. The calculated results obtained from this modified formula are contrasted with those got by the use of the Rankine and wedge formulas for a continuous and unlimited surcharge, in tables, and are also illustrated by a series of curves.

With the board vertical the modified formula gives rather low values at the lower level, but agrees fairly well at the higher with experiment. The wedge and Rankine formulas for unlimited slope give values too great by 20 per cent. and 50 per cent. respectively.

The experimental values obtained with the board inclined inward fall below in the sand tests, especially at the lower level, what might be expected, but this is considered to be due to some accidental cause. Otherwise, agreement is maintained between the moment calculated from the modified formula and experiment. With the unlimited-slope formulas the calculated values are about 40 per cent. in excess.

Corresponding agreement exists in the case of the board inclined outward, the unlimited slope calculated values showing an excess of about 50 per cent.

Viewing the whole series of experiments the greatest discrepancy occurred with the 7-ft. levels (no surcharge) when gravel filling was used, and was worst with the board inclined outward. Low experimental values were also obtained in the sand tests at the lower level under surcharge.

The results of the experiments may be said to justify the following conclusions :—

1. That the overturning moment on retaining walls due to the filling, as calculated from a general formula based on the wedge theory, is approximately the same as ordinarily exists when the filling behind the wall is uncompacted, when the height is within the limits of these experiments, and when the inclination of the inner face of the wall either outward or inward is not greater than usually obtains in practice.

From this it would follow that the following assumptions which were made may be taken as warranted :

(*a*) That the resultant pressure on a unit length of wall makes an angle equal to the angle of repose with the normal to the wall.

(*b*) That the position of the resultant pressure is at a point on the inner face distant one-third from the bottom of the wall.

2. That in the case of walls with a filling whose surcharge is not continuous and unlimited, the general formula requires modification. This can be done by reducing the sliding prism of irregular section to one equivalent triangular section from which the overturning moment can be deduced either by direct calculation or by a convenient graphical method.

The position of the resultant pressure may under these conditions range from 0·33 to 0·364 of the inner face of the wall measured from its base.

* Abstract of paper read before the Institution of Civil Engineers, on Tuesday, February 10, 1920.

"WATER-COOLED TURBO-ALTERNATORS."

To the Editor of Engineering.

Sir,—We would point out an error in Mr. J. Shepherd's letter to you on "Water-Cooled Turbo-Alternators," and which was published in your issue dated February 6. The output of the Parsons' alternators to which he refers is 11,000 k.w., at 75 per cent. power factor, giving an output of 14,700 k.v.a., and not 10,000 k.v.a. as stated.

Yours faithfully,
For C. A. Parsons and Co., Limited.,
J. Bedford, Secretary.

Heaton Works, Newcastle-on-Tyne,
February 13, 1920.

"THE CAMMELLAIRD-FULLAGAR OIL ENGINE."

To the Editor of Engineering.

Sir,—The comments made by Mr. Everett in your issue of February 6, on the above engine, call for some reply. The greater portion of the first paragraph of the letter referred to is irrelevant to the subject, and as the statement on piston cooling is simply criticism with nothing in the nature of reasoned argument, no reply can be given. It is sufficient to say that the system of piston cooling adopted is a well-known and tried one, and with minor improvements has been used on the "Cammellaird-Fullagar" engine during four years of intermittent running with no signs of trouble.

The breakdown of a piston in the "Cammellaird-Fullagar" engine would be no more serious than a similar occurrence in any other type of oil engine. In both cases it would only put one cylinder out of action. The piston is now beyond question one of the most reliable parts of all oil engines, and if, by the heart of the engine, Mr. Everett means the part most likely to give trouble, he must look for it amongst the parts which the principle of the opposed piston engine has eliminated.

The consumption of piston lubricating oil will, of course, vary with the size of the piston and the surface velocity. In the case of the "Cammellaird-Fullagar" engine both are considerably reduced, so that this point of your correspondent loses its significance.

Mr. Everett's remarks on scavenging are somewhat coloured by his familiarity with the type of engine he quotes, and he has made a serious blunder when he states that the onesided port scavenging is the best of the three methods illustrated. No oil engine designer would challenge the supremacy of the opposed piston engine as regards scavenging whatever else he may think of the earlier three-crank per cylinder constructions. Even if no experimental verification was available, it could be assumed that with simple scavenging the percentage of air left in the cylinder with side port scavenging is easily the least. It cannot be assumed that arranging the three methods of scavenging for supercharging, will improve the relative position of the side port arrangement in this respect. If supercharging is desired it can be obtained with the opposed piston engine in a much simpler fashion than by adding camshaft-operated slide or rotary valves. In the case of the engine under discussion it is not necessary to resort to supercharging to get high outputs. With simple scavenging, mean pressures of 140 lb. per square inch have been obtained. Such results are, of course, far in excess of what is generally considered expedient to put into every day practice. The rating of 67 lb. brake mean pressure mentioned for the 1,000 brake horse-power engine is simply to give an easy running engine as experience has shown that the best running engines are similarly rated, as the "space saved" advantage of the new engine is so great, this can easily be afforded. If future experience shows that rating can be economically increased, it will be found that the opposed piston engine will be the last to call a halt.

There are no reasons, functional or structural, why the "Cammellaird-Fullagar" engine cannot run at the piston speed of 600 ft. per minute without making an abnormal engine. Prolonged runs at piston speeds of 720 ft. per minute have been made, and even 900 ft. is quite economical, the scavenging air pressure being only 2½ lb. per square inch at these high speeds.

The comparison of the Fritz engines with the new engine is also perfectly legitimate. The original engines were designed about ten years ago, but these were not fitted into any ship. The engines of the Fritz are of later date, the ship is quite new and, so far as can be ascertained, had not carried a cargo up to the time of her surrender. The engines of the Fritz are 3 ft. 6 in. shorter than the original engines, and any further shortening could only be done by methods which one would be quite justified in applying to shorten the "Cammellaird-Fullagar" engine still further. At any rate it should be some satisfaction to engineers in this country to know that these results have been accomplished by a purely British invention.

Yours faithfully,
D. M. Shannon.

24, Village-road, Birkenhead,
February 17, 1920.

FUSION WELDS.

To the Editor of Engineering.

Sir,—I have read with considerable interest Mr. Joseph Shepherd's letter in Engineering of February 6, page 176, respecting the use of quasi-arc welds in modern boiler-making, and also your footnote to it. It does not appear to be generally known that seams made by the quasi-arc process are very often put in boilers now, and also in air receivers and subsidiary vessels which work at high pressures. Quite a number of the leading firms of boiler makers have put welded seams in parts of boilers which are in compression when they are at work, for some time, and up to the present I have not heard that any accident has occurred through the failure of a quasi-arc welded seam. The uptakes of vertical boilers from the smallest to the very largest sizes have had the longitudinal seams welded by this process for some time, and the uptakes have proved very satisfactory under the severest conditions of working. It is difficult to roll an uptake into the truly cylindrical form, and a small peak is often left where the two edges of the longitudinal seam join. To remove this peak or ridge, the uptakes are heated and passed again through the rolls, after the quasi-arc welds have been made. This is a very severe mechanical test of the weld, but a properly and carefully-made weld will stand this treatment without showing any indications of cracking or distress. In view of this, such welds may be deemed satisfactory for this class of work. The welding induces a little hardening of the plates adjacent to the weld, but not enough to take exception to, when the weld is in compression.

A Lancashire boiler was fitted, about six months ago, with a pair of new furnaces, the longitudinal seams of which were welded by the quasi-arc process. The furnaces were made to replace others which had collapsed through overheating due to shortness of water, and owing to the time which would have been lost in procuring new plates to make rings similar to the ones which collapsed, the furnaces were each made in one ring about 6 ft. long, from stock plates. The plates were of sufficient thickness for the original working pressure and of suitable boiler quality. No signs of sweating or weakness were detected during the hydraulic test of 210 lb. per square inch, after completion of the repairs, and the furnaces are working satisfactorily to-day.

One very important advantage quasi-arc welds have over fire welds, is, that there is no reduction in thickness, due to hammering and the repeated heating of the plates in the fire, such as is often found even in the best shops, with fire welds. Quasi-arc welding has been used to unite the fire-box crown to the fire-box, to join the two halves of pressed fire-boxes together, and also to join girder bars to fire-box crown plates, all with satisfactory results.

Some of the more progressive boiler-making firms, are welding the shells of small high-pressure boilers and air receivers by this method, but owing to the reluctance of some of the insurance companies to accept these welds when in tension, they are usually reinforced with a covering strap, riveted on. It seems very possible that before long this reluctance will die out, and welds in tension will be accepted, as the method of manufacture becomes more widely known and further experience is gained.

Yours faithfully,
Jas. R. Edwards, A.M.I.Mech.E.

18, North Parade, Lincoln, February 12, 1920.

THE DESIGN OF CONNECTING-ROD FORKS.

To the Editor of Engineering.

Sir,—With reference to Mr. Bogert's letter on connecting rods for internal-combustion engines which appeared in your issue of January 23, it would seem on examination that, in the comparison between the common or standard type of rod, and that proposed, the difference

in the stresses quoted is rather one of calculation than of fact.

The stresses in the former case are evidently calculated on the assumption that the fork is subject to the simple loads shown as W and $\frac{W}{2}$ in the sketch, Fig. 1, and that these are the only forces acting on it. In such a case any section of the fork is subjected to a bending moment $\frac{W}{2} \times h$ as well as a simple pull or push given by $\frac{W}{2} \sin \theta$, and f_p, the stress induced is therefore given by $f_w + f_w$, where

$$f_w = \frac{\frac{W}{2} \times h}{I} \cdot y \quad \text{and} \quad f_w = \frac{\frac{W}{2} \sin \theta}{A}$$

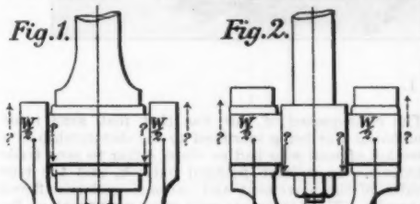
The stresses quoted for the old type of forks agree with this analysis.

A fallacy in the calculation, however, lies in the assumption that the external loading at the section considered is entirely as represented in the figure, i.e., entirely given by the load $\frac{W}{2}$ and the single couple $\frac{W}{2} \times h$.

It is obvious that this could only truly represent the facts if, and when, no bending moment were transmitted from the gudgeon-pin to the fork, and, whether the pin is separate from the fork or carried in it, *this could only be the case when the parts in question were absolutely unstrained and therefore absolutely unstressed.*

As soon as stresses occur at the crosshead, a slight strain must take place in the crosshead pin, and this must bring in fresh forces and couples (somewhat as shown dotted in figure) which tend to counteract the original couple $\frac{W}{2} \times h$ and the stresses produced by it.

In the case in which the pin is carried in the connecting rod, the induced couple produced by these secondary



forces must be very nearly equal in magnitude to the original couple $\frac{W}{2} \times h$ and the bending stresses, due to the two combined, must therefore be very nearly negligible. Even in the other case, where the pin is only connected to the fork by the usual crosshead bearings, the effect of the secondary couples must be considerable, since, even if the bearings are slack, their surface contact must necessarily extend over a given finite length of pin, and therefore they must transmit to their respective forks, at least the bending moment sustained by the pin over that finite length.

The original simple couple, moreover, is calculated on the assumption that the loads are evenly distributed over the surfaces which support them, and therefore that the resultant forces act through the middle points of the bearings in question.

Any strain, however, such as that indicated above, must so alter this distribution as to bring the resultant forces nearer the centre of the fork, and thus reduce the originally assumed couple on which the stresses are calculated. The stresses calculated with the original assumption as to loading must in either case, therefore, be considerably in excess of those actually sustained under working conditions, and, in the case of the fork, which is rigidly connected to the gudgeon pin, so far in excess as to make the calculations almost valueless.

This, indeed, is tacitly recognised in the calculations of stresses in the new type of fork as proposed by Mr. Bogert. The effect of the cross-tie is, in fact, apparently taken as nullifying all bending effect in the lower part of this fork although the same system of external loading involves as much bending moment here as in the forks of the older type.

The truth is that in any type of rod the crosshead pin fulfils to a certain extent the function of the cross-tie which is the feature of Mr. Bogert's design.

In the type of fork in which there is a single gudgeon pin carried in the jaws of the rod itself, the cross-tie action must be about as positive as in Mr. Bogert's design, and much more effective since it applies to the whole fork and not only to the lower part of it.

With a double gudgeon pin as carried on the piston-rod crosshead, the tie action is not so obvious, but the induced couple caused by the slight bending of the pins must produce at all events part of the effect of a tie, and in both types of rod therefore the loading as assumed in the original calculation must give much too high a value in the stresses calculated even though those actually occurring are not, perhaps, so low as those calculated for Mr. Bogert's fork.

With the rods of actual engines which have, in fact, been running without fracture for years, the value of f_p as calculated on the above assumption, will commonly be found to exceed 13,000 lb./in.² in forks which are separate from the gudgeon pin, and 15,000, or even 18,000 or 19,000 lb./in.², in forks of the stronger type.

Assuming that 30-ton steel is used, *the maximum permissible compressive stress without any margin of safety at all* is 6,533 lb./in.² for a reversible load, 9,800 lb./in.² for a non-reversible live load, and only 19,600 lb./in.² for an absolutely dead load, and it is absurd to think that, with the conditions of reversibility and shock obtaining in actual running any stress as high as 19,000 lb./in.², or even 13,000 lb./in.², could be sustained for a considerable period without fracture.

With the assumptions used, then, the calculated stresses bear no close relation to those that actually occur, and unless the bending moment, which is directly transmitted to the forks by the gudgeon pin, is included in the loading, no close approximation can be expected. The transmitted moment, however, is not very susceptible of calculation, or even accurate estimation, and for design purposes it has up to the present apparently been preferred to neglect it altogether and allow imaginary stresses, which are therefore excessive.

In marine engine design, in fact, the stresses found from the old basis of calculation may safely be allowed to go as high as 13,000 lb./in.² in forks which do not carry the gudgeon pin, or 16,000 lb./in.² or 18,000 lb./in.² in forks in which the gudgeon pin is rigidly fixed.

It should not be thought, then, that those stresses are actually likely to occur since they are really only the result of a quite imaginary loading which happens to be convenient for calculation. The imaginary loading produces an imaginary stress, and to obtain the real stress some sort of design factor will be necessary as a multiplier, just as in other cases.

It is not fair, therefore, to compare these stresses with those calculated on other assumptions. It is, in fact, probable that each will require a "design factor" of its own, and while the old assumption certainly requires a factor which has the effect of reducing the calculated stresses, it is probable that the one used in Mr. Bogert's proposal will require a factor which increases them.

Whether it is a paradox or not, it is a very well known and well-worn fact that, with certain supposed external systems of loading and internal reactions assumed to correspond to them, the addition of metal to certain parts may increase the stresses supposed to occur there rather than decrease them—but whether the assumptions either as to the external loading or the internal reactions which produce these stresses are always borne out in fact is rather another matter.

In the case of the extremely originally shaped fork of Mr. Bogert's article; and particularly in that part of it which is above the tie rod, it seems very doubtful whether the simple conditions of loading assumed are likely to be justified at all, and in this case the results arrived at do not achieve much more than to serve as an illustration of the extraordinary incompleteness of the assumptions and theories on which designers are compelled to base their calculations.

Yours faithfully,

February 9, 1920. S. G. W.

THE INDIAN PUBLIC WORKS DEPARTMENT.

TO THE EDITOR OF ENGINEERING.

SIR,—May I be permitted to draw the attention of your readers to a new development in the treatment of this public service by the Government of India.

Resolution No. 1085-E.A. of the Finance Department, dated Delhi, November 15, has recently been sent out for action; a resolution purporting to be for the purpose of giving effect to the recommendations of the recent Royal Commission, for the improvement of pensions.

The twenty-year pension in the P.W.D.—the only remaining attraction to really educated engineers—has been "improved" as follows: (1) The amount has been left unaltered—at a time when all other wages and pensions in the civilised world are going up to meet the increased cost of living; (2) an entirely new condition has been coupled with the grant of it, *i.e.*, that it is "subject to the absolute right of Government to decline to permit any officer to retire before reaching the age of superannuation."

Those who know India at present also know that the Government of India will not be in a position much longer to "permit" any civil engineer to leave India, once he is caught; and the choice before those now entering the service, and those in it at present who are forced to accept the new terms, will be poverty or slavery.

Nothing will change the policy of those who at present direct the Government of India; I write merely to warn engineers who intend to enter the P.W.D. that the service is being (intentionally or unintentionally, it is not for me to say) degraded to a classification with certain services which have always been associated with academical failure, and that they will be better off as mechanics in England than as civil engineer officers in what was the finest engineering service in the world.

As an officer of long and approved service I warn intending candidates, and those who are not yet finally ensnared, that it is now impossible honestly to earn a reasonable living in the Indian Public Works Department. Those interested should, in their own interests, write to the Secretary of the Civil Engineers Association at Simla.

I cannot, of course, detail all the steps we are about to take or have taken, as these matters are necessarily "confidential," but I will let any *bona fide* correspondent know why and how it is steadily becoming impossible for any self-respecting, educated civil engineer to live in the engineering service with perhaps the finest traditions in the world.

Yours, &c.,

"BUREAUCRAT."

FLUID MOTION AND VISCOSITY.

TO THE EDITOR OF ENGINEERING.

SIR,—The criticisms by Colonel R. de Villamil in your issue of the 13th inst., of my article on fluid motion, are very amusing. Colonel de Villamil evidently imagines that whenever $f(v\,l/\nu)$ is used in mathematical work it represents a series in positive powers of $v\,l/\nu$ only, or in other words a Taylor's series in that variable. It is only a question of definition, and in my case I used that adopted by mathematicians. The term $f(v\,l/\nu)$ means that the quantity or function under consideration depends upon $v\,l/\nu$ and varies as this quantity varies. One might say with equal truth that it varies with $\nu/v\,l$, in which case we may write it as $f_1(\nu/v\,l)$ using a suffix, since the form of the function will be different although its actual value is the same. If Colonel de Villamil prefers it in the latter form no objections will be raised provided he does not conclude thereby that it is a series in positive integral powers only. In this respect, however, he falls into error.

It might interest some of your readers to know that for the steady motion of a fluid in two dimensions the differential equations of motion give the infinite series.

$$R = \rho\,\nu\,v\,l\left\{a + b\left(\frac{v\,l}{\nu}\right) + c\left(\frac{v\,l}{\nu}\right)^2 + \&c.\right\}$$

where a, b, &c., depend upon the geometry of the problem. Colonel de Villamil's equation:

$$R = \rho\,v^n\,l^m\,(1 + \nu/v\,l)$$

is a particular form of this, but in spite of that his form is incorrect. It is not accepted generally, as he imagines, and is not confirmed experimentally. His logic in deducing $n = 0$ and $n = 1$ is unsound. So also is the statement:

"$f(v\,l/\nu) = f(v\,l/0) = f$ (infinity)

and the *resistance is infinite.*" This shows a misunderstanding of the meaning of a function.

With regard to the last point raised by Colonel de Villamil, viz., Du Buat's paradox, I might say that it is neither accepted generally, nor has it any foundation.

Yours truly,

W. L. COWLEY.

National Physical Laboratory, Teddington,
February 16, 1920.

BROWN COAL DISCOVERED IN COURLAND.—According to an announcement in the Lettish Information Bureau's Bulletin, a seam of brown coal, 5 ft. thick and extending 100 versts (66·3 miles) has been discovered in Courland. The quality of the coal is described as differing little from that of black coal, and it is estimated that the quantity would suffice for the needs of the Latvian railways and shipping for a decade.

FRENCH COMPANY FOR RECONSTRUCTION OF DEVASTATED AREA.—We read in *The Board of Trade Journal* that a new company has been formed at Paris under the name of Société Auxiliaire de Reconstruction Immobiliere et Industrielle for the carrying out of work of every kind connected with the reconstruction of the devastated regions. The office of the company is at 99, Rue des Petits-Champs, Paris, and its capital is 500,000 francs.

TRADE PROPAGANDA IN BRAZIL.—The Porto Algere Branch of the British Chamber of Commerce of Sao Paulo and Southern Brazil points out, says *The Board of Trade Journal*, that great quantities of correspondence, circulars, catalogues, &c., in Portuguese are coming into Brazil by every mail from the United States, whereas comparatively little comes from the United Kingdom. The Chamber accordingly recommends to British manufacturers the publication and wide distribution in Brazil of propaganda literature such as booklets, catalogues, circulars, &c., in Portuguese, in order to counteract other competing propaganda.

EXPECTED INCREASE IN PRICE OF AMERICAN CARS.—The American press, says *The Board of Trade Journal*, forecast an advance in the prices of American cars, for although the output of motor cars in the United States has been steadily increasing and almost every producer is working at full capacity, manufacturing costs are compelling an increase in the selling prices. The following table, showing prices of eight prominent makers of motor cars in 1915 and 1919 gives the actual increases:—

	1915. (Dols.	1919. Dols.
Dodge	785	1,085
Ford	440	525
Hudson	1,550	2,200
Maxwell	695	985
Mercer	3,000	4,500
Pierce-Arrow	5,000	7,750
Stutz	2,450	3,350
Overland	850	1,065

INDUSTRIAL NOTES.

In our last week's issue we referred briefly to the question of payment by results which had been dealt with at a recent conference at York. The conference took place between the Engineering and the National Employers' Federations, the Workers' and several other unions. It was jointly decided to recommend a memorandum of agreement for acceptance by the respective constituent bodies. The proposals are subject to acceptance as a whole, and are standard, not minimum proposals. They are to come into effect on and from the fourth full pay day after acceptance. They deal with overtime, night shift, holidays and payment by results. The payment by results clauses read as follows :—

Employers shall have freedom to introduce systems of payment by results satisfactory to the men and the employer concerned, subject to the following conditions :—(1) In all cases the time rate of the workmen concerned shall be guaranteed, irrespective of earnings. (2) Overtime, night shift, Sunday, and holiday allowances shall be paid in addition to earnings under any system of payment by results, on the same conditions as already prevail in the trade and district in question for time work. (3) The price to be paid, or the basis time to be allowed either for a new job, or for an altered job, shall be fixed by mutual agreement between the employer and the workmen who are to perform the work, or by such other methods as may hereafter be established by agreement in any trade or district. (4) No piece-work price, bonus or basis time once fixed may be altered, unless the material, means or method of production is changed. (5) When the material, means, or method of production is changed, and the employer desires a modification in price or basis time, the modification shall in no case be such as to effect a reduction in the earnings of the workers concerned. (6) When piece-work, bonus or basis time system is in operation and an employer desires a workman or workmen to undertake a job for which no price or basis time has previously been fixed, the employer shall, either before or as soon as possible after the job has been given out, see the workman or workmen concerned with a view to agreement in accordance with the terms of this agreement. (7) In the event of a workman taking exception to any price or basis time allowed and being unable to arrive at a settlement, the matter shall be dealt with by a deputation of workmen, consisting of the workmen affected, and two others engaged in the branch of trade in the shop concerned, who shall endeavour to effect a settlement with the management within seven days. (8) All settlements shall be retrospective to the commencement of the job on which the question is raised. (9) No debit balance shall be carried forward beyond the weekly or other mutually recognised period of settlement. (10) All balances and wages shall be paid through the office in proportion to the time worked and time rates of the workman or workmen on the job. (11) The employers shall in all cases supply the workmen with a card stating the nature of each job, and the price or basis time allowed, such card to be retained by the workmen for reference until the completion of the job. (12) Piece work prices and bonus or basis times shall be such as will enable a workman of average ability to earn at least 33½ per cent. over present time rates (excluding war bonuses).

It was agreed that a special conference shall be held at an early date to discuss schemes of systems of payment by results, such as to include within their scope those men whose work is contributory to production, but who are not directly engaged on a productive process.

It was agreed that the consolidation of war wages should be the subject of a special conference to be held at an early date.

Mr. Brace moved, in Parliament, on Wednesday, the 11th inst., an amendment to the Address, expressing regret at the absence from the King's speech of any proposal to nationalise the coal mines of the country on the lines recommended by a majority of the members of the Royal Commission on the Coal Industry which was appointed for the purpose of advising the Government on the best methods of reorganising the industry in order to secure economy in management, greater safety in working and maximum output.

After discussion, there voted for the amendment 64, against 329, or a majority against of 265.

In the course of one of his recent election speeches at Paisley, Mr. Asquith is reported to have stated that he was in favour of the acquisition by the State of mineral rights and royalties, and of the establishment of boards on which employers and employed, and the State as trustees for the consuming community should be associated in the control and management of the industry. Nationalisation, he added, would enthrone the rule of bureaucracy, tend to stereotype progress, paralyse individual initiative and enterprise, reduce output and sooner or later impoverish the community.

HORIZONTAL LOG-CUTTING BAND SAW.

CONSTRUCTED BY MESSRS. THOMAS ROBINSON AND SON, LIMITED, ROCHDALE.

(For Description, see opposite Page.)

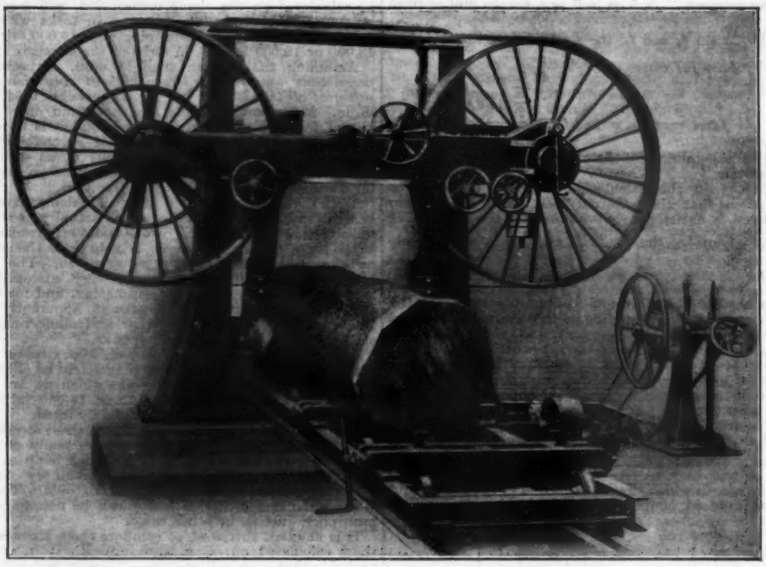


Fig. 1.

A meeting was held last Friday at Victoria Hall, Sheffield, when Mr. W. L. Hichens, chairman of Messrs. Cammell Laird and Co., spoke on the co-operation of Capital and Labour. Mr. Hichens stated that this co-operation was not only possible, but was also essential. The two were mutually indispensable. It was idle to argue that Labour produced all the wealth and that Capital had no share. Capital was nothing else than savings and had it not been for the thrift of past generations, we should not have had the railways and other products of civilisation which we had to-day. It was suggested that the Government should be the only capitalist; that it should get capital by taxation and loan it to the various industries and individuals. Government control had shown that any large industry was far too big a thing to be managed by a Government Department, with one man at the head of it. It was also suggested that various guilds should run the industries and provide the capital. That also was unworkable, because the whole essence of capital was that a great deal was wanted at one moment, and this could not be provided out of revenue. If the railways were run by a guild, and it was decided to electrify a considerable number of them, a terrific sum of money would be required, which could not possibly come out of revenue.

We read in *The Iron Age*, New York, that the Department of Labour, New Jersey, has completed the compilation of statistics showing the advance of wages of workers in industrial lines from 1914 to 1918. Twenty-five typical State industries were selected for the estimates, including the following: 174 machinery plants, which report a 93·6 per cent. annual advance per worker; in 16 steel and iron forging plants the average income advanced from 712 dols. to 1,334 dols. per year; 19 wire-drawing and wire cloth plants show an annual pay roll total of 120·5 per cent. larger per worker than previous to 1914; 14 steam boiler manufacturing plants report an advance of 115·2 per cent. in employees average annual earnings; structural steel and iron workers show an increase of 92 per cent. in wages between 1914 and 1918, or 603 dols. and 1,158 dols. per annum respectively.

Speaking at a meeting held last Monday at Hebburn-on-Tyne, under the auspices of the National Alliance of Employers and Employed, Mr. W. J. Hazzard said it must be recognised that the trade union movement when built upon the sanest foundations could be regarded as a national asset. Greater interest, however, had to be taken in the movement by those who subscribed to its membership; unfortunately, indifference and mental blindness were apparent at the majority of the branch meetings of different unions. The consequence of this was that real, sane trade unionism was being sacrificed to the dictatorship of a section of men who had no claim either to sane trade unionism or to sane political outlook, and the true value of the movement and national welfare suffered thereby. The extremists who were most anxious for the overthrow of Constitutionalism would do well to remember that a revolution would simply usher in a period of tyranny. Labour conditions were not so ideal in Soviet Russia as the extremists would have us believe, and messages from Russia indicated that a 12-hours' working shift had been substituted for the 8-hours' working day, on account of Russia's grave economic position.

It is stated that the Shipbuilding and Engineering Trades Federation have decided to withdraw from the negotiations with the National Union of Railwaymen, on the question of their respective members in the railway shops, and to repudiate the railwaymen's authority to speak and to negotiate on behalf of the craft unions. This action brings to a deadlock negotiations which have proceeded between the National Union of Railwaymen and the other unions since 1911, and is understood to have been precipitated by the publication of the terms which the National Union of Railwaymen proposed to make in complete settlement of the wages, issues on which the negotiations were commenced. A committee of the Federation is to consider the matter. In the meantime, the Federation have presented an application on behalf of all their members, including shopmen, for an increase of 15*s.* weekly for workers over 18 years of age and of 10*s.* weekly for apprentices and boys. The hearing of this application is to take place before the Industrial Court on the 25th and 26th inst., but it is deemed advisable by the workmen's representatives, it is further reported, to consider the whole future policy on wage advances, and to this end a conference between the shipbuilding and engineering trade representatives will be held at the same time. The proposals of the National Union of Railwaymen were to the effect that members of the craft unions who obtained work in the railway shops had to retain the membership of their union and to pay the National Union of Railwaymen a nominal contribution per week, and, further, that during the period of employment of these men in the railway shops their working conditions had to be negotiated by the National Union of Railwaymen.

Personal.—Mr. Thomas Bayley, 30, Reconquista, Buenos Ayres, announces that he has been appointed representative for South America by Messrs. A. G. Kidston and Co., of London, Glasgow, New York and Montreal.

HORIZONTAL LOG-CUTTING BAND SAW.

CONSTRUCTED BY MESSRS. THOMAS ROBINSON AND SON, LIMITED, ROCHDALE.

Fig. 2.

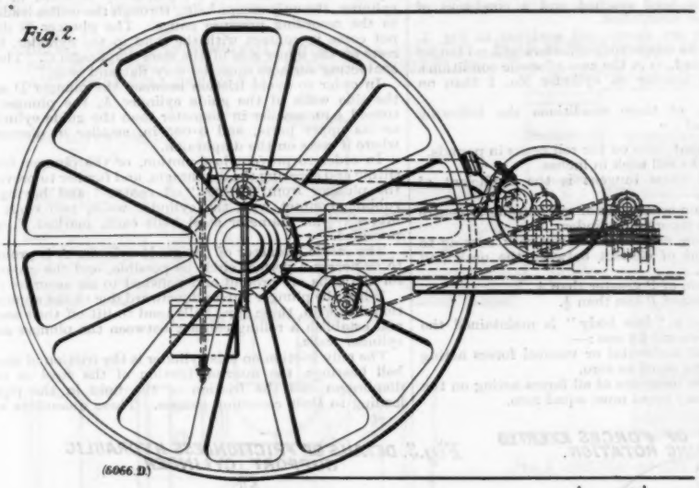


Fig. 3.

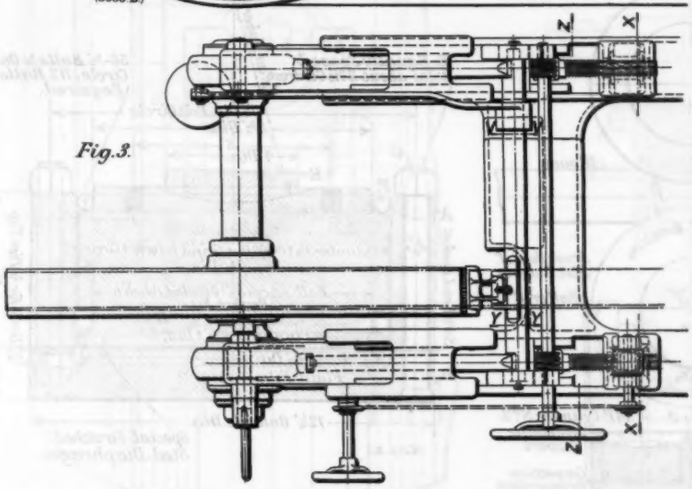


Fig. 4.

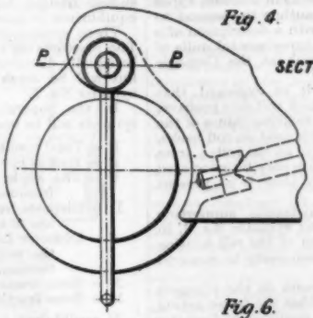


Fig. 5. SECTION AT P.P.

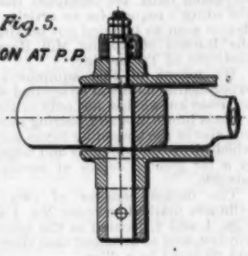


Fig. 6. SECTION THRO' ROCKING SHAFT AT V.V.

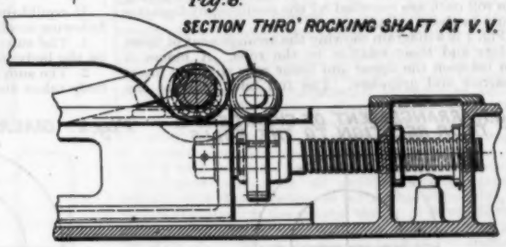


Fig. 7. SECTION AT X.X.

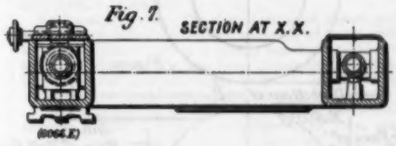


Fig. 8 SECTION AT Z.Z.

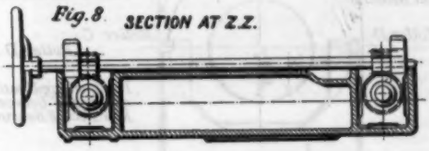


Fig. 9 SECTION AT Y.Y.

We illustrate on the opposite and present pages an improved tensioning gear applied to horizontal log-cutting band saws, by Messrs. Thomas Robinson and Son, Limited, Rochdale. Fig. 1, page 257, shows a typical machine so fitted, though the remaining figures are illustrations from another size of machine in which the positions of the loose and fixed pulleys are reversed. The machine consists of the usual two standards with a cross-rail at the top. The cross-slide moves vertically on the standards, its position being controlled by vertical screws in the standard housings. The cross-slide is fitted with adjustment so that wear on the vertical faces can be taken up.

The pulleys are mounted on heavy shafts, the wheel fits being tapered. The pulleys are fixed by a large fine-thread nut. They are carefully balanced, and ground on the face. The movable pulley is shown in Figs. 2 and 3, and details of its mounting in Figs. 4 to 8. As will be seen from these figures, it is carried in bearings suspended from two frames, which are telescopic with the main cross-slide. The adjustment of these frames is independent of the tensioning gear. Figs. 2, 3 and 6 show these telescopic frames to be fitted at their inboard end with horizontal screws capable of being rotated by a hand wheel, spindle and two worms and gears shown in further detail in Fig. 8. By means of this screw gear the frames are worked out or drawn in, according to the length of the saw. The pulley shaft is carried in bearings hung from these frames (see Figs. 2, 4 and 5). They are suspended on an eccentric pin, and the whole may be swung in by rotating this pin by the handle shown. The lining of the pulleys is secured by the device shown in Fig. 7, which represents a section at X X, in Fig. 3, *i.e.*, at the in-board end of the gear. This lining arrangement consists in an additional worm gear, worked by a hand wheel and chain, which works one of the main adjustment screws in or out, thus swinging the shaft. The screw on the front of the cross-slide is therefore subjected to two adjustments; that at the back to one only.

The straining or tensioning device consists of a shaft mounted eccentrically in ball bearings and provided with a lever from which an adjustable weight is suspended. The weight is adjusted according to the saw in use. The tension is transmitted to the saw by a knife-edged strut or distance piece, one end of which fits into a recess in the eccentric shaft, and the other into a recess in the shaft bearing, as illustrated in Fig. 4. The weight tending to rotate the shaft pushes the bearing out by means of this rod. Fig. 9 shows the scraper and brush fitted for cleaning the rim of the movable pulley. The driving pulley is fitted with a brush and oil pad.

The saw guides in these machines are adjustable, and are provided with hardwood packings, with scrapers to keep the saw clean. A lubricating pad is carried in one guide. The feed is arranged so that the carriage may be started, stopped or reversed by a single lever. Another lever is provided for raising or lowering the cross-slide and pulleys, the depth of cut being indicated on a revolving scale. The feed is arranged with variable speed gear, consisting of a V-belt running on expanding cone pulleys.

ELECTRICITY SUPPLY.—In pursuance of his powers under the Electricity (Supply) Act, 1919, the Minister of Transport has appointed Sir John F. C. Snell, M.Inst.C.E., to be chairman of the Electricity Commissioners, and Mr. H. Booth, O.B.E., of the Board of Trade; Mr. W. W. Lackie, C.B.E., M.Inst.C.E., M.I.E.E., and Mr. Archibald Page, M.I.E.E., to be Commissioners. All communications for the Commissioners should be addressed to the Secretary, Electricity Commissioners, Gwydyr House, Whitehall.

ELECTROLYTIC PRODUCTION OF HYDROGEN AND OXYGEN.—The electrolytic cells of the Geeraerd system, used in the military plant built early in 1918, near Rouen, differ from those we described in our recent article of the above title, on page 513 of our issue of October 17 last, by not having a porous diaphragm. The plant, as described by Lieutenant-Colonel T. A. Ross, late R.A.F. and R.E., who designed and erected it, in *The Electrical Review* of January 2, is one of two originally planned for a total production of 100,000 cub. ft. of oxygen and twice that amount of hydrogen per day of 20 hours. The plant is provided with two Diesel engines, each of 550 brake horse-power, Crompton generators and petrol motors for auxiliary machinery. The 2,600 electrolytic cells are arranged in 52 groups of 50 cells, four groups being connected in series. A cell is built up of two dished cast-iron electrode plates which are bolted together and finely corrugated on the inside, the cell forming a narrow vertical trough, as in the other cases we mentioned. Against each plate rests a system of glass vanes arranged like a Venetian blind, the horizontal vanes being separated by distance-pieces of ebonite; the two blinds of a cell are both inclined inward, leaving a free space in the middle of the cell where the diaphragm would be in other cells. The gas bubbles leaving the plate electrodes are deflected by the vanes to collect in a small chamber above after having passed through separators which keep the electrolyte back. Each plate is cast with two holes in the upper part of the flange, and when the cells are themselves bolted together, these holes unite to form gas conduits. One hardly expects that the hydrogen and oxygen will be sufficiently prevented from intermixing by the Venetian blinds, and it is indeed mentioned that the gases are sent through purifiers containing electrically-heated coils of platinum wire and platinised fibre; "by these means the purity can be raised, if necessary, above 99·7 per cent."

FRICTION AND SPREADING FORCES IN ROLLING MILLS.*

By W. B. SKINKLE,† Pittsburgh, Pa.

THE need of accurate knowledge of the forces acting on rolls and the friction losses on roll necks in different types of rolling mills has prompted the author to respond to the editor's request for an article, with a description of a device soon to be tried out on the experimental mills of the Bureau of Rolling Mill Research at the Carnegie Institute of Technology.

By means of this equipment it is expected that experimental data will be secured which will give positive, accurate knowledge, not only of the relative values of the various lubricants and bearing metals used on roll necks, but also of the spreading forces acting on the rolls; from which the stresses in rolls and housings may be calculated to a far greater degree of accuracy than is at present possible.

The device consists of two hydraulic supporting cylinders marked cylinder No. 1 and cylinder No. 2, in Figs. 1 and 2, located in the bottom of the roll-housing window, and so arranged that they can easily be removed and replaced by a filler.

The carrier for the bottom roll rests on the plungers of these cylinders in such a manner that the forces acting on the roll neck are recorded by the resulting hydrostatic pressure in these cylinders.

In Fig. 1 is a diagram showing the arrangement of these cylinders and their relation to the rolls. A bloom is shown between the upper and lower rolls with the lower roll carrier and cylinders. The full lines indicate the position of this carrier under static conditions (condition of rest). The conditions existing at the neck of the lower roll are greatly exaggerated for the purpose of illustration.

The total spread force F, due to the bloom being pinched between the rolls, will cause a heavy force P to be applied‡ about as indicated in Figs. 1 and 2. Under static conditions this force would be transmitted from the body to the neck, and would be applied to the bearing as indicated by the arrow A, in Fig. 1. Such an application of forces would cause one-half the load P on each bearing to be carried by cylinder No. 1 and the other half by cylinder No. 2.

The proportion of the total force F which is distributed to each neck of the rolls will depend on the location of the pass in the roll body and can readily be figured by the well-known principles of beam reactions.

Where rotation starts, and the bloom is being rolled, the point of contact between roll neck and bearing changes to some other point, the force P is then applied to the bearing as indicated by the dotted arrow B, and the lower roll carrier has a tendency to assume a position indicated by the dotted lines, using the roller C as a fulcrum point, the roller D lifting off its seat. The position indicated by these dotted lines in Fig. 1 of course is greatly exaggerated for the purpose of illustration. It is vitally important, however, that the bearing be perfectly free to rotate as indicated, and that no forces other than cylinders Nos. 1 and 2 be interposed to prevent this rotating tendency. (In actual practice it is expected that not more than 0·003 in. or 0·004 in. of movement will be obtained on these cylinders between no load and their maximum carrying capacity of 250,000 lb. each.)

When the contact point has moved to a place where it slides back as rapidly as it tends to climb, the angle of sliding friction has been reached and a condition of equilibrium is again established.

These conditions are shown and analysed in Fig. 2. The pressures on the supporting cylinders will no longer be equally distributed, as in the case of static conditions, but will be much heavier on cylinder No. 1 than on cylinder No. 2.

In the analysis of these conditions the following symbols will be used:—

P = Total resultant force on the roll necks in pounds.
R = Radius of the roll neck in inches.
U = The angle whose tangent is the coefficient of friction.
D = Distance from centre line of roll housing to centre line of supporting cylinder.
d = Distance from centre line of roll-neck bearing to the point of contact between the neck and bearing.
N = Some fraction of P greater than ½.
M = Some fraction of P less than ½.

If equilibrium in a "free body" is maintained the following conditions must be met:—

1. The sum of all horizontal or vertical forces acting on the body must be equal to zero.

2. The sum of the moments of all forces acting on the body taken about any point must equal zero.

Fig. 1. ARRANGEMENT OF CYLINDERS & THEIR RELATION TO THE ROLLS.

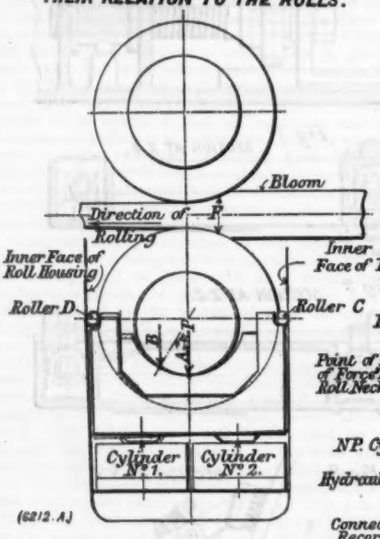


Fig. 2. DIAGRAM OF FORCES EXERTED DURING ROTATION.

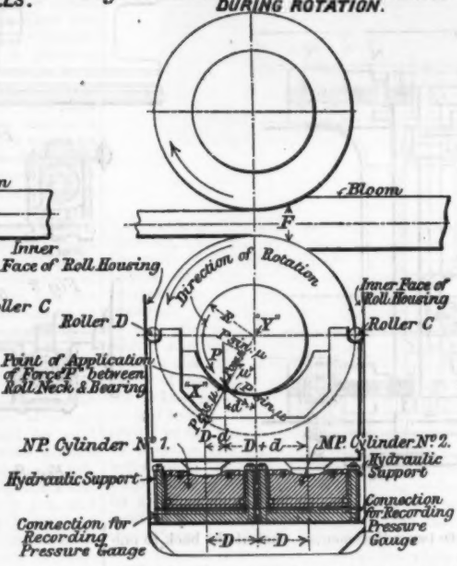
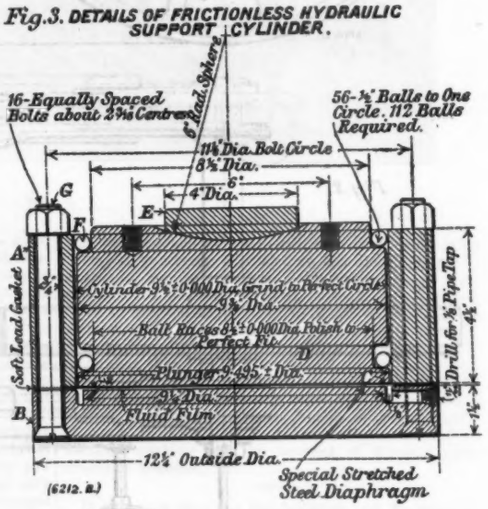


Fig. 3. DETAILS OF FRICTIONLESS HYDRAULIC SUPPORT CYLINDER.



Fulfilling the first condition, as applied to the vertical forces on the lower roll-neck bearing, we have $-P + NP + MP = 0$, whence $NP + MP = P$. Cancelling the P's, we have:

$$N + M = 1.$$

This shows that for each increase of over half the total load carried by cylinder No. 1 there is a corresponding decrease in the load carried by cylinder No. 2 and that the sum of the pressures on cylinders Nos. 1 and 2 must be equal to the force P. This same fact can be shown by taking moments about the point *x* where the roll neck supplies its load to the bearing. In this case the force P has no lever arm. Its moment would therefore be zero, and it may be neglected. Taking moments about *x* we have:

$$+NP(D-d) - MP(D+d) = 0$$

which expands into:

$$NPD - NPd - MPD - MPd = 0 \quad . \quad (1)$$

Taking moments about Y, the centre of the roll neck, we have:

$$-Pd + NPD - MPD = 0 \quad . \quad . \quad (2)$$

The foregoing is true only if the hydraulic support cylinders are frictionless. If these hydraulic cylinders were of the ordinary hemp-packed plunger type the results obtained would be almost useless as the friction of the packing on the plunger would be very large and the exact amount of this friction would be very difficult if not impossible to determine.

It will therefore be necessary to produce a frictionless hydraulic support cylinder. This, the author believes, has been practically obtained in the cylinder shown in Fig. 3. While it is recognised that no machine can be absolutely frictionless, this cylinder so nearly approaches this ideal state that for all practical purposes it may be considered as frictionless.

The cylinder consists of an upper guide cylinder A, securely bolted to its base B by sixteen ¾-in. bolts G. The base, which is really the cylinder proper, has a groove 9½ in. inside diameter cut into it. The centre portion of the base is then faced off to allow just a film of fluid not over ¼ in. in thickness to act on a special stretched-steel diaphragm C, which is securely held in place by the friction between the parts A and B of the cylinder, and is made tight on its lower side by a soft lead gasket. By this means the fluid is completely confined in the cylinder, the only escape being through the orifice leading to the recording pressure gauge. The plunger D does not come in contact with the fluid in the cylinder, but rests on the upper side of the steel diaphragm C. These contacting surfaces must be very flat and true.

In order to avoid friction between the plunger D and the side walls of the guide cylinder A, the plunger is turned ¼ in. smaller in diameter than the guide cylinder on its upper parts, and 0·005 in. smaller in diameter where it rests on the diaphragm.

In order to prevent lost motion, or the plunger from tilting and shearing the diaphragm, and further to prevent the plunger from getting "off centre" and having a rubbing contact with the cylinder walls, two rings of fifty-six ½-in. diameter steel balls each, marked F, are provided.

The inside diameter of the guide cylinder A is ground to as nearly a perfect circle as possible, and the grooves for the balls are ground and polished to an accurate fit.

When the plunger moves downward due to the application of a load, these steel balls tend to lift off their seats and establish a rolling contact between the plunger and cylinder walls.

The only friction on this cylinder is the friction of these ball bearings, the internal friction of the steel in the diaphragm and the friction of the fluid in the pipes leading to their recording gauges. These quantities are so small when compared with the maximum load of 250,000 lb. which each cylinder is designed to carry, that they may be neglected.

The displacement of fluid by the plunger when under load is equally small. Marks' "Mechanical Engineers' Handbook" page 251, gives the following information: "A pressure of 1 lb. per square inch compresses liquids in volume as follows: Water, 1 part in 300,000; mercury, 1 part in about 4,700,000. For water in an iron pipe this corresponds to a compression of 2 in. per mile of length for a pressure of 10 lb. per square inch."

It will easily be seen that such a compression of the fluid will not disturb the roll setting. The only other factors entering into the plunger displacement are the quantity of fluid necessary to move the needles of the recording gauges and the expansion of the short pipes leading to these gauges. Both of these factors are so small that they may be neglected.

The idea of this frictionless diaphragm cylinder is not new, but has had several stages in its development. It appears to have been originally invented by Mr. Emery, who first applied it to the well-known testing machine bearing his name. The general application of this invention was delayed by the fact that Mr. Emery measured the pressure in his hydraulic supports by means of a complicated balancing and weighing mechanism. The hydraulic support was made accessible to general use by the research work of Dr. A. Martens at the German Government materials testing station, who measured the pressure in the hydraulic support by means of Bourdon pressure gauges and who proved conclusively that the combination of hydraulic support and pressure gauges forms the most accurate and desirable means for measuring without friction or lost motion, forces of any magnitude and of any suddenness of application.

Professor W. Trinks, head of the department of mechanical engineering at the Carnegie Institute of Technology, first conceived the idea of applying cylinders of this type to roll necks sometime early in 1916, and made drawings of a special roll housing for this purpose.

When the author was placed in charge of the organisation of the Bureau of Rolling Mill Research and of the designs of the experimental mill, he carried the development one step further by designing the present cylinders in such a manner that they would fit in the window of an

* Description of apparatus designed for a special series of investigations to be made on the experimental rolling mill at the Carnegie Institute of Technology. Reproduced from *Blast Furnace and Steel Plant*.

† Director, Bureau of Rolling Mill Research, Carnegie Institute of Technology. Mem.Am.Soc.M.E.

‡ It is not the purpose of this article to enter into a discussion of the complicated system of forces at the contact surfaces between rolls and bloom. Inasmuch as the rolls are able to move up or down and are restrained from horizontal movements in any direction by the bearings and roll housing, the resultant of all forces acting must be in a vertical direction.

ordinary roll or pinion housing, and could easily be replaced by a filler casting in case experiments not requiring their use were to be made.

The first cylinder of this type is now in the course of construction and will be carefully tested and calibrated under a 600,000-lb. compression testing machine before the final design is produced for the experimental mill.

DETAILS OF MILL SHOWING BOLT WITH "BALL JOINT" TO PROVIDE FLEXIBLE CONNECTION BETWEEN THRUST PLATE AND LOWER ROLL CARRIER.

SECTION ON LINE H.H.

Fig. 4.

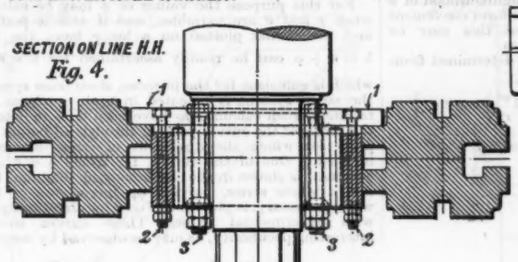


Fig. 5.

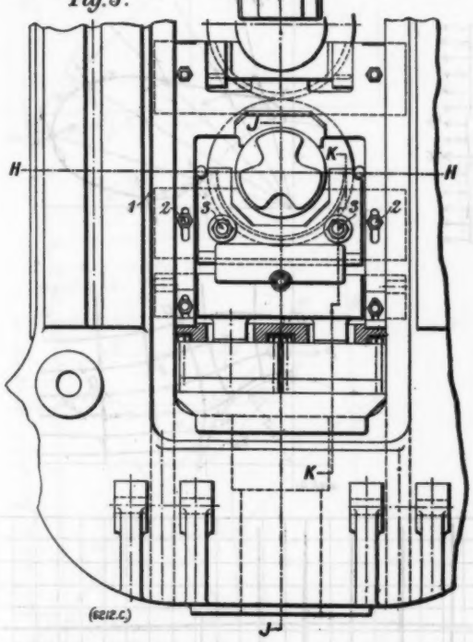


Fig. 6. DETAILS OF BOLT SHOWN IN FIG. 5

SECTION ON LINE K.K.

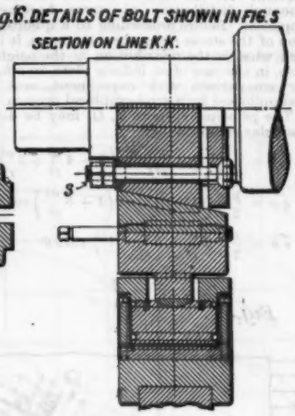
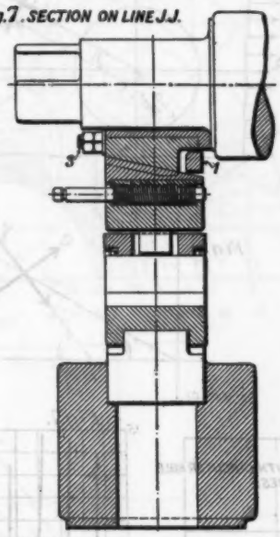


Fig. 7. SECTION ON LINE J.J.



Diaphragms varying in thickness from 1/64 in. to 3/64 in. are on hand, and their relative merits together with the relative merits of mercury or water for the fluid will be carefully investigated before the final selections are made.

Figs. 4 to 7 show these cylinders applied to the 18-in. three-high bar mill, which are somewhat different from those shown in Figs. 1 and 2. These last-mentioned figures were taken from the 24-in. sheet mill with the neck brass "faked in" for the purpose of better illustration of the mechanical principles involved.

There is one more important item which should be considered before bringing this article to a close. That is the friction of the end of the roll-neck brass on the roll body.

The "thrust plate" marked "1" in Fig. 4 is held firmly against the inside of the roll housing by bolts 2 and 3, and, unless a flexible connection between the lower roll carrier and this thrust plate were provided, would offer a very substantial resisting force acting against the rotating tendency of the lower roll carrier. To overcome this bolts 3 are made with ball joints at their inner ends. In this manner any retarding action due to the stationary thrust plate is avoided. Fig. 6 is a section through this bolt, and clearly shows the construction.

The importance of careful experiments on roll-neck friction will be realised when it is stated that, according to the best information at present available, between 40 per cent. and 50 per cent. of the total work of a blooming or bar-mill engine is absorbed in friction on the roll necks. These figures represent the best working conditions in rolling-mill practice. For mills such as plate, skelp or sheet mills rolling wide, thin sections, which are often cold, the work lost in friction on the roll necks is frequently between 70 per cent. and 80 per cent. of the total work of the engine or motor.

The designs of the experimental mills are being worked out with extreme care, which of necessity involves a slow rate of progress. They offer a great many problems similar to the one just described. It is expected that these designs will be completed some time during the next three or four months, and will be given to the public very shortly thereafter.

The Carnegie Institute of Technology is throwing open to members of the Bureau nearly 400,000 dols. worth of building and equipment, free of all charges for rentals, &c. More than half the money necessary to add this experimental rolling mill has already been definitely subscribed, and the remainder is in sight. The completion of this experimental mill will make the Bureau of Rolling Mill Research what is probably the largest and most complete steel research laboratory in the world.

DANGER IN THE USE OF COAL DUST.—The decreasing supply of natural gas, says *The Iron Age*, New York, has largely resulted in the greater use of pulverised coal, and elaborate installations have recently been made in the steel plants to powder the coal and convey it to the furnaces. It has been found, however, that soon after the furnaces commenced to operate with the pulverised coal, large quantities of fine dust began to accumulate on the platforms over the furnaces, the roof trusses, on the outside of the various pipe lines, electric cables, and on the roofs of the buildings. Some of the companies, becoming alarmed requested the Bureau of Mines to ascertain the liability of this dust to cause an explosion. While conducting an investigation an explosion occurred in another mill, which caused the death of one man and severely burned two others.

RISE OF PRICES IN GERMANY.—The prices of iron and steel products continue to rise in Germany. The Steel Union has raised the quotation for iron sections from 1,750 marks to 2,470 marks, and for bar iron from 1,745 marks to 2,500 marks. The meeting of the mine-owners of the Coal Syndicate held at Essen on January 24, decided to apply to the National Coal Union for a rise in prices to take effect from February 1, on account of the increased wages, the higher cost of materials, and the expenditure needed to restore the mines to the same rate of production as before the war. It was also stated, that the Becker Steel Works, at the instance of the National Industrial Minister, had joined the Rhenish-Westphalian syndicate with the "Präsident" mine from February 1. The Union of Galvanised Iron Products has raised the additional price from 100 per cent. to 150 per cent., and the Sales Bureau for pressed and rolled lead products has raised the price by 100 marks per 100 kg., the quotation now standing at 1,170 marks.

PHOTO-ELASTIC AND STRAIN MEASUREMENTS OF THE EFFECTS OF CIRCULAR HOLES ON THE DISTRIBUTION OF STRESS IN TENSION MEMBERS.*

By Professor E. G. COKER, M.A., D.Sc., F.R.S., K. C. CHAKKO, M.Sc., and Y. SATAKE, University College, London.

THE effect of a hole on the stress distribution in a tension member of rectangular section is of considerable importance in practical work, since in nearly all engineering operations holes are drilled or otherwise shaped for connecting pieces together, and although in most cases the stress is applied by a rivet filling the hole, yet there are numerous instances in practical work in which the experiments, to be described, are very closely represented. In roof trusses and bridges, for example, compression and tension angle bars and rectangular tension members often occur in pairs, and are held together at intervals by rivets, which latter usually transmit no forces to the members themselves. Other instances of a more complicated kind occur in the frames of machines in which groups of elements, connected by bolts and rivets, are unavoidably diminished in section by holes for constructional reasons. Most of these cases are more complicated than those investigated here, but there is a certain amount of advantage in selecting simple cases for experiment, since the general character of the stress distribution is more easily perceived, and its application to more involved cases is likely to be attended with less error, than if an attempt is made to use the investigation of one complicated example to another case in which the various circumstances which cause the complexity are of a different nature. Simplicity in the conditions is, in fact, most essential for real progress in experimental knowledge, and especially so in connection with problems on stress distribution in materials.

Engineers endeavour to avoid stressing materials beyond their elastic range, so far as that is possible, and with this limitation the general theory of stress distribution in materials is very complete, although the great majority of problems, of special interest to engineers, still remain unsolved.

So far as is known, the distribution of stress produced by a central hole in a tension member of finite width has not been worked out as a purely mathematical problem, although the problem has been successfully attacked for both circular and elliptical holes in plates of infinite width on the usual assumption of elastic theory.†

Experimental determinations of the stress distribution around a hole in elastic materials have been made by various investigators, such as those by Messrs. Wilson and Gore, in which the strains are measured in perforated rubber sheets. In a recent paper‡ the stress around a hole in a tension member, which is permanently deformed, is considered by determining the hardness of the surface of the material at various points. It is there shown that hardness increases with tensile stress, according to a linear law, after the elastic limit has been passed.

Curves of equal hardness are drawn for over-stressed material, and the stress at any point is apparently inferred by the relation previously established between hardness and the stress in a bar of uniform section permanently deformed by tension. It seems probable that our scanty knowledge of the stresses in materials in the plastic stage may be appreciably extended by this method.

The present paper is an extension of some experimental work,§ undertaken by one of us on transparent plates to find the nature of the distribution around a circular hole. This earlier work was manifestly incomplete, since no attempt was then made to separately determine the principal stresses P, Q, at a point, and only the value (P − Q) was measured by aid of the change in the temporary double refraction produced by stress. The theory of the infinite plate shows that the minor principal stress is comparatively small, and indeed vanishes altogether at the internal contour where the stress reaches its maximum value and also at the parallel sides, so that, from a practical point of view, little was lost by the limitation of the earlier work, although there remained a number of interesting questions, requiring much precise measurement, especially for the determination of the $f(P, Q)$ which would allow of separate measurements of P, Q, and their inclinations λ_p, λ_q, and so complete the experimental analysis. The methods and apparatus used are described in earlier papers,‖

* Paper read before the Institution of Engineers and Shipbuilders in Scotland, November 18, 1919.

† C. E. Inglis, "Stresses in a Plate Due to the Presence of Cracks and Sharp Corners." Trans. Institution of Naval Architects, 1913. See also A. E. H. Love, "Treatise on the Theory of Elasticity," first edition, vol. i, Chap. xii; and H. Lorenz, "Lehrbuch der Technischen Physik," vol. iv, Art. 55.

‡ "Stress Lines in Steel after Permanent Deformation," by Andrew McCance, D.Sc., A.R.S.M. Trans. Institution of Engineers and Shipbuilders in Scotland, vol. lxii.

§ "The Determination, by Photo-Elastic Methods, of the Distribution of Stress in Plates of Variable Section, with Some Application to Ships' Plating," by E. G. Coker. Trans. Institution of Naval Architects, 1911. Also, "The Effects of Holes and Semi-Circular Notches on the Distribution of Stress in Tension Members," by E. G. Coker. Proc. Physical Society, London, vol. xxv, 1913.

‖ E. G. Coker, "Polarised Light and its Applications to Engineering," Royal Institution, Friday evening discourse, 1910, and "Photo-Elasticity for Engineers." Proc. Institution of Automobile Engineers, November, 1917.

and need not be referred to here. For convenience, sheets of nitro-cellulose were used, as in previous work, and some of the specimens tested were originally made in 1911. The $(P - Q)$ stresses are independently measured and, as the results show by comparison with the earlier figures, the ageing effect in the material is very small. One of the questions to which the present investigation is directed relates to the contour value along the parallel sides, and around a centrally placed hole. In both cases, since there are no applied forces at

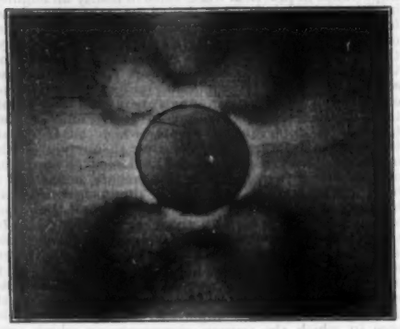


FIG. 1.

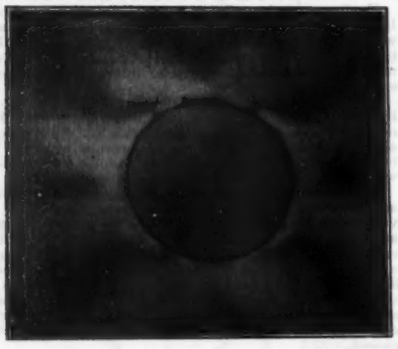


FIG. 2.

hole is enlarged progressively. With a hole of $\frac{1}{16}$ in. diameter, in a plate of 1 in. width, there is no visible indication of any variation of stress along the external contours, but if the hole is enlarged to, say, $\frac{1}{4}$ in. diameter, Fig. 1, it is at once evident from the colour bands that there is a non-uniform distribution of stress along the sides with maximum values on each side of the minimum section. As the hole is further enlarged, Fig. 2, this unequal distribution of stress becomes increasingly apparent. Before proceeding to a quantitative examination of the stress along these contours, it is of interest to find what is the distribution in the neighbourhood of a hole, in the case of an infinite plate, in a form convenient for comparison with experiment, and this may be accomplished by a semi-graphical process.

The principal stresses P, Q, may be determined from the polar components :—

$$\widehat{rr} = \frac{p}{2}\left\{\left(1 - \frac{a^2}{r^2}\right) + \left(1 - 4\frac{a^2}{r^2} + 3\frac{a^4}{r^4}\right)\cos 2\theta\right\}$$

$$\widehat{\theta\theta} = \frac{p}{2}\left\{\left(1 + \frac{a^2}{r^2}\right) - \left(1 + 3\frac{a^4}{r^4}\right)\cos 2\theta\right\}$$

$$\widehat{r\theta} = \frac{p}{2}\left\{3\frac{a^4}{r^4} - 2\frac{a^2}{r^2} - 1\right\}\sin 2\theta$$

Fig.3.

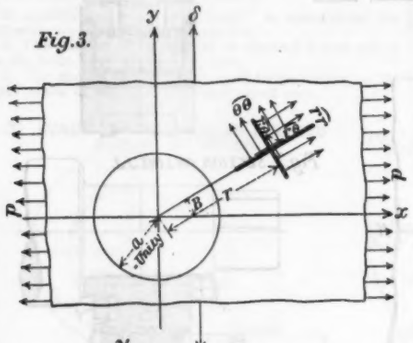
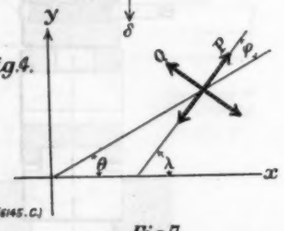


Fig.4.



which the direction of the principal stress makes with the radius vector to a point, Figs. 3 and 4. For any given values of θ and ϕ the values of r can be determined by solving a quadratic equation in $\frac{1}{r^2}$, but the labour involved in calculating a sufficient number of isoclinic lines in this manner is very great, as may be inferred from the fact that if θ and ϕ are varied by increments of 5 deg., the number of equations to be solved is 17×19, or 323 in all, and a more indirect method of attack is therefore advisable.

For this purpose the values of ϕ may be calculated when r and θ are variables, and if this is performed and the results plotted on a log r base, the values $\lambda = \theta + \phi$ can be readily ascertained for $0 < \theta < \frac{\pi}{2}$, which is sufficient for the purpose, since from symmetry the stress system is repeated in each quadrant. The results of such calculations have been used to determine the forms of the curves passing through all points of the plate for which the directions of stress are equally inclined. One of the curves, for which $\lambda = \theta + \phi =$ constant, is shown in the accompanying diagram, Fig. 5, and a whole series, varying by increments of 1 deg. where necessary, is plotted in Fig. 6 for direct comparison with experimental values. These curves show an interesting peculiarity, as may be observed by inspection.

Fig.5.

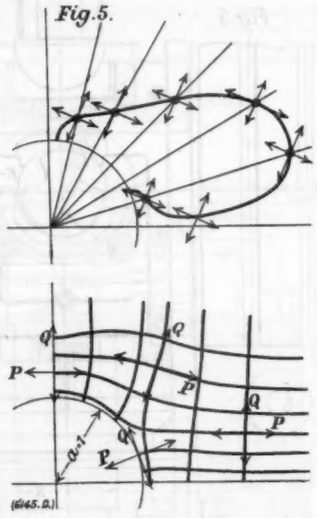


Fig.6.
INFINITE PLATE IN TENSION WITH CIRCULAR HOLE.
ISOCLINIC LINES.

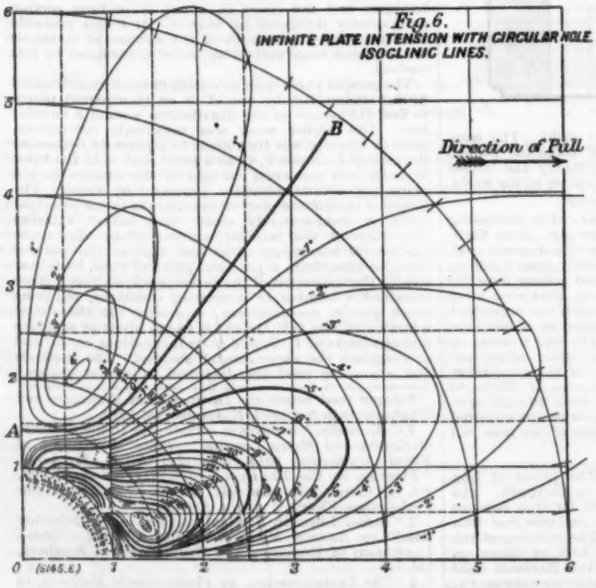
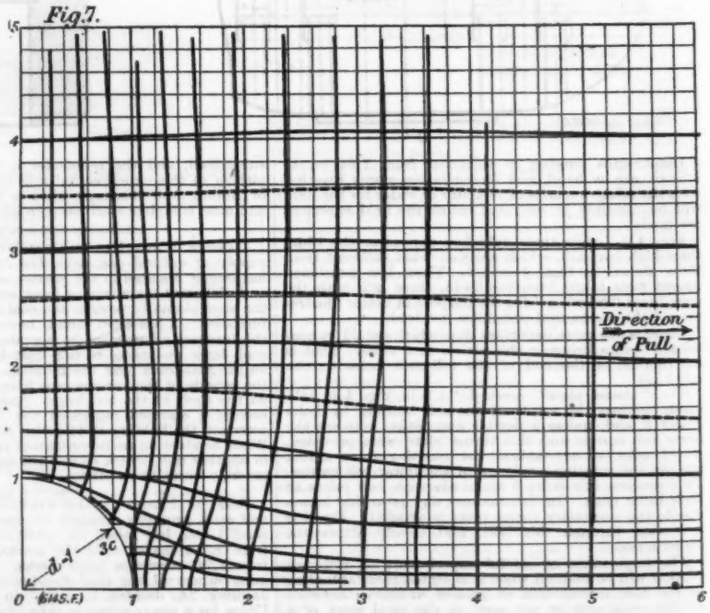


Fig.7.



these contours, there can be no normal stress there, while these boundaries are themselves lines of principal stress, to which the other principal stress curves are orthogonal. The values of $(P + Q)$ and $(P - Q)$ therefore coincide along these contours, and may be used to check one another in an experimental determination.

A qualitative examination of holes of various sizes in a finite width of plate shows that, at the straight boundaries, the maximum stress in the direction of the pull is not necessarily at the minimum section. This is apparent from the appearance of specimens in which the

in the following manner. It can be shown that

$$P + Q = \widehat{rr} + \widehat{\theta\theta}$$

$$P - Q = \sqrt{(\widehat{rr} - \widehat{\theta\theta})^2 + 4 \cdot \widehat{r\theta}^2}$$

$$\tan 2\phi = \frac{2\widehat{r\theta}}{\widehat{rr} - \widehat{\theta\theta}} = \frac{\left(1 + \frac{2}{r^2} - \frac{3}{r^4}\right)\sin 2\theta}{\left(1 - \frac{2}{r^2} + \frac{3}{r^4}\right)\cos 2\theta - \frac{1}{r^2}}$$

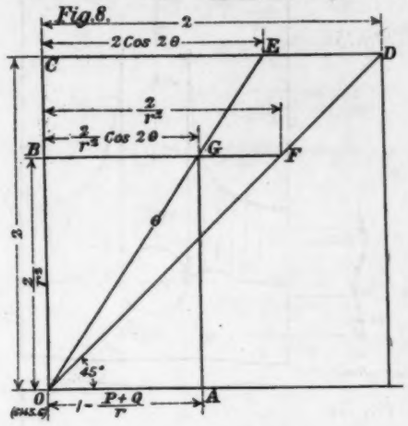
where the value of a is taken as unity and ϕ is the angle

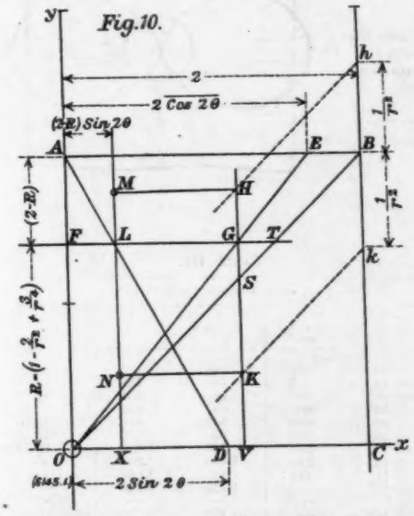
The curve A B divides the quadrantal area into two parts, for which, on one side, nearly all the lines of principal stress corresponding to the direction normal to pull are inclined at angles of less than $\frac{\pi}{2}$, and on the other at angles greater than $\frac{\pi}{2}$. The area bordering the hole from $0 < \theta < \frac{\pi}{6}$ is, however, an exception. In general, therefore, these curves of principal stress in the longitudinal direction have maximum ordinates at the

isoclinic line $\lambda = 0$ if they cut this line, and therefore they approach the axis of pull at all other points within the quadrantal area considered.

The lines of principal stress may be determined fairly accurately by marking their directions at a sufficient number of points along the isoclinic lines, and drawing curves tangential to these directions, commencing from any arbitrary point.

The process may be carried out more accurately by selecting any point (x, y) at which the inclination λ is known, and determining the position of a neighbouring point $(x + \delta x, y + \delta y)$ by the relation $\delta y = \delta x \tan \lambda$.





The limit of accuracy is then conditioned by the smallness of δx and the closeness of the isoclinic curves. This latter process is adopted in the chart, Fig. 7, showing the lines of principal stress for a considerable area around a hole in a tension member of infinite width. The values of the principal stresses P, Q, and also P + Q, P − Q, for comparison with observations on finite widths of plate, are directly obtainable from the solution, but they are more readily obtained by a semi-graphical process which it is convenient to describe here.

We have :

$$P + Q = \widehat{rr} + \widehat{\theta\theta} = p\left(1 - \frac{2}{r^2}\cos 2\theta\right)$$

or,

$$1 - \frac{P+Q}{p} = \frac{2}{r^2}\cos 2\theta,$$

and values of this expression may be readily found graphically by constructing a rectangular chart, Figs. 8 and 10, as follows :—

Take $OC = CD = 2$; $CE = 2\cos 2\theta$; $OB = \frac{2}{r^2}$, Fig. 8, and draw B G F parallel to C D and intersecting O E in G. Then B G or its projection O A is the value sought. Conversely, if it is required to determine the value of r corresponding to any possible values of $\frac{P+Q}{p}$ and θ, the quantity $1 - \frac{P+Q}{p}$ can be marked off along the horizontal axis and the line $AG = \frac{2}{r^2}$ gives the required value of r. A series of these values are plotted on Fig. 9, and are shown by dotted lines.

To determine the value of P − Q the following construction may be adopted, based on the relations,

$$P - Q = \sqrt{(\widehat{rr} - \widehat{\theta\theta})^2 + 4\,\widehat{r\theta}^2}$$

$$\frac{\widehat{rr} - \widehat{\theta\theta}}{p} = \left(1 - \frac{2}{r^2} + \frac{3}{r^4}\right)\cos 2\theta - \frac{1}{r^2} = R\cos 2\theta - \frac{1}{r^2}$$

$$\frac{2\,\widehat{r\theta}}{p} = \left(1 + \frac{2}{r^2} - \frac{3}{r^4}\right)\sin 2\theta = (2 - R)\sin 2\theta$$

where $$R = \left(1 - \frac{2}{r^2} + \frac{3}{r^4}\right).$$

On a rectangular chart, Fig. 10, construct a square O A B C of 2 units side, and mark off on the side O C, the value $OD = 2\sin 2\theta$, and on the side A B the value $AE = 2\,\overline{\cos 2\theta}$ where the sign $\overline{\ \ }$ denotes that the value of $\cos 2\theta$ is taken with a positive sign. On the side O A mark off $OF = \left(1 - \frac{2}{r^2} + \frac{3}{r^4}\right) = R$; then $AF = (2 - R)$. Draw F L G T parallel to O C, intersecting A D in L, O E in G, and O B in T, and project L and G on to the side O C, giving intercepts X and V. Then :

$$FG = OV = R\,\overline{\cos 2\theta}, \text{ and}$$

$$FL = OX = (2 - R)\sin 2\theta = \frac{2\,\widehat{r\theta}}{p},$$

also :

$$VS = OV = R\,\overline{\cos 2\theta}.$$

Mark off on the vertical through B the values $BA = Bk = \frac{1}{r^2}$ and draw parallels to O B through the points A, k, to intersect the vertical through G in H and K. Project these latter points on to the vertical through L to give the intersections M and N ; then

$$VH = VS + SH = R\,\overline{\cos 2\theta} + \frac{1}{r^2}$$

$$VK = VS - SK = R\,\overline{\cos 2\theta} - \frac{1}{r^2}$$

Now if $\theta < 45°$, $\cos 2\theta$ has a positive value and

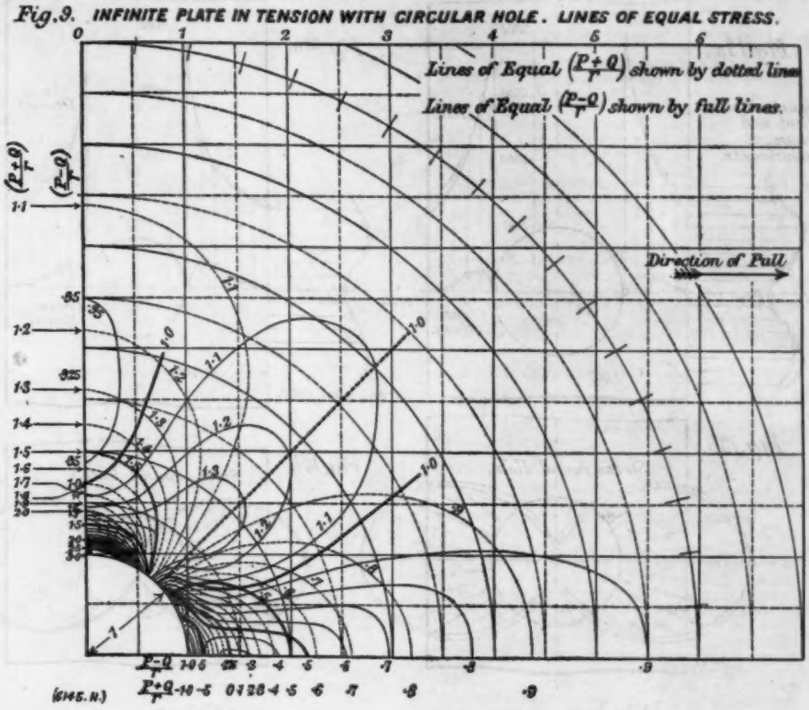
$$\frac{\widehat{rr} - \widehat{\theta\theta}}{p} = VK.$$

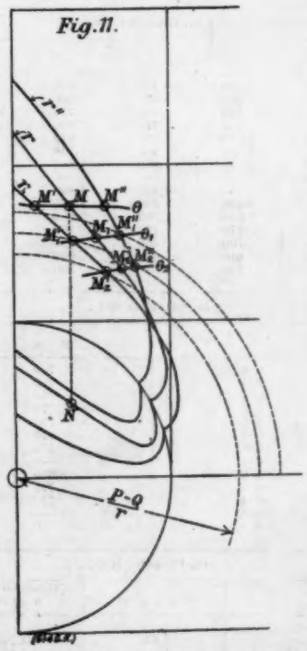
If $\theta > 45°$, $\cos 2\theta$ is negative and

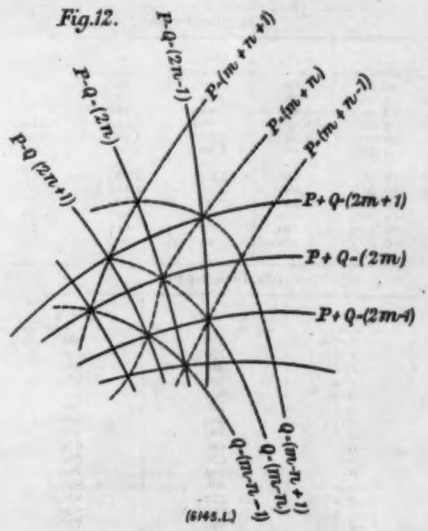
$$\frac{\widehat{rr} - \widehat{\theta\theta}}{p} = -VH.$$

$$\therefore\ OM = \sqrt{OX^2 + XM^2} = \sqrt{OX^2 + VH^2}$$

Fig.9. INFINITE PLATE IN TENSION WITH CIRCULAR HOLE. LINES OF EQUAL STRESS.







$$= \frac{1}{p}\sqrt{(\widehat{r\,r-\theta\,\theta})^2 + 4.\widehat{r\,\theta}^2} = \frac{P-Q}{p}, \text{ if } \theta > 45°$$

$$ON = \sqrt{OX^2 + XN^2} = \sqrt{OX^2 + VK^2}$$

$$= \frac{1}{p}\sqrt{(\widehat{r\,r-\theta\,\theta})^2 + 4.\widehat{r\,\theta}^2} = \frac{P-Q}{p}, \text{ if } \theta < 45°$$

for the given values of r and θ.

points D and E for given values of θ. Then for a definite value of r, and varying values of θ, a series of curves on which the points M lie can be found, Fig. 11. Similarly if θ is fixed and r is varied a second set of curves may be constructed intersecting the first set. With these two systems it is possible to read off values of r, θ, corresponding to any given values of $\frac{P-Q}{p}$ or *vice versa*.

The full series of curves used in constructing the diagrams in which full lines denote $\frac{P-Q}{p}$ and dotted lines $\frac{P+Q}{p}$

The former correspond to the isochromatic lines given in the polariscope, and may therefore be used for comparison with the stress in plates of finite width.

It may also be noted that from this form of chart the value of 2ϕ can be found, and therefore the isoclinic lines can be drawn.

This is at once seen from the relation :

EXPERIMENTAL VALUES OF STRESSES AT AND NEAR A CIRCULAR HOLE IN A TENSION MEMBER.

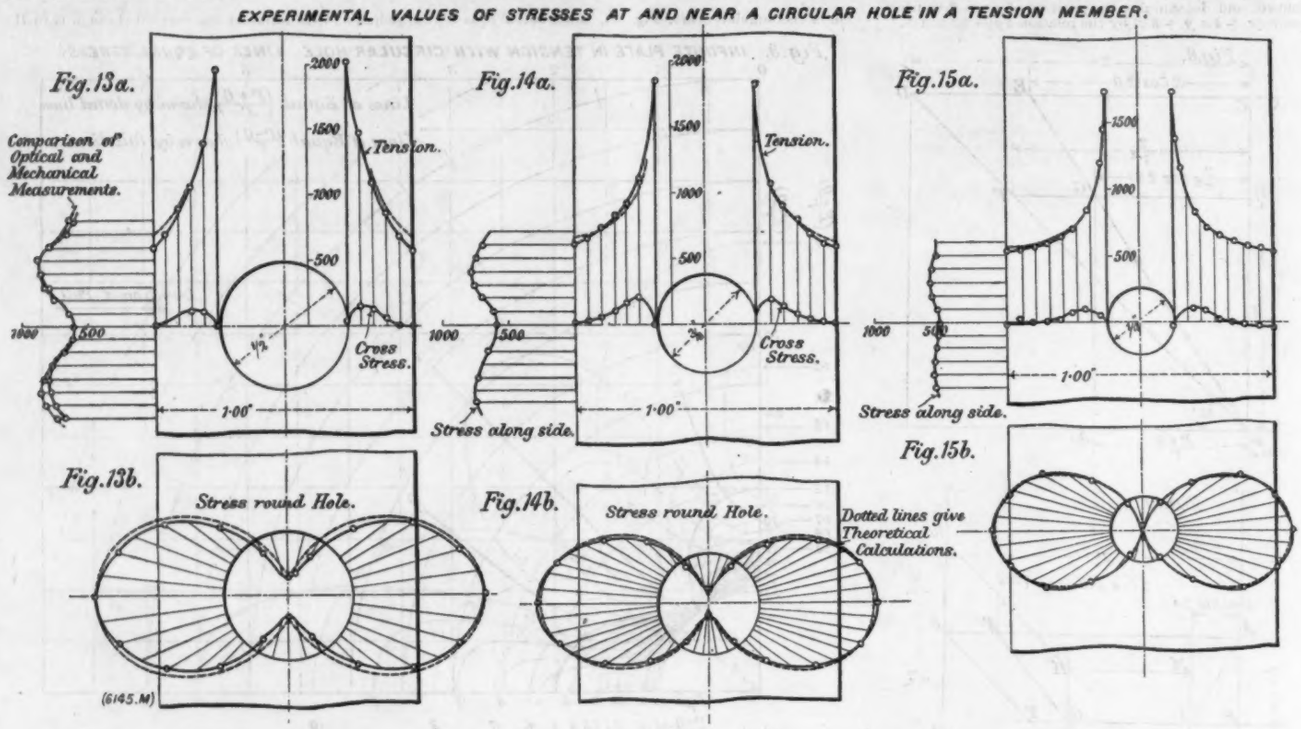


TABLE I.

¼-In. Diameter Hole.

x	$p+q$	$p-q$	p	q
−0·50	590	600	595	− 5
−0·45	700	690	695	+ 5
−0·40	890	880	895	+ 5
−0·35	1,170	950	1,060	110
−0·30	1,500	1,300	1,400	100
−0·25	—	1,960	1,960	0
0	—	—	—	—
+0·25	2,050	2,000	2,025	25
+0·30	1,630	1,320	1,475	155
+0·35	1,230	960	1,095	135
+0·40	900	830	865	35
+0·45	640	690	615	− 25
+0·50	600	—	600	—

¼-In. Diameter Hole.

y	$p+q$	$p-q$
0·7	670	650
0·6	770	790
0·5	840	880
0·4	800	850
0·3	800	830
0·2	740	—
0·1	580	620
0·0	590	600
−0·1	640	620
−0·2	620	660
−0·3	780	760
−0·4	800	820
−0·5	770	830
−0·6	720	820
−0·7	660	730

¼-In. Diameter Hole.

θ	$p-q$	Calculated Value $p = 652$.
deg.		
0	1,960	1,955
15	1,800	1,780
30	1,190	1,315
45	490	650
60	−280	0
75	−600	−480
90	−700	−650

TABLE II.

⅛-In. Diameter Hole.

x	$p+q$	$p-q$	p	q
−0·50	610	570	590	20
−0·45	660	600	630	30
−0·40	760	660	710	50
−0·35	910	710	810	100
−0·30	1,070	760	915	155
−0·25	1,300	900	1,100	200
−0·19	—	1,860	1,860	—
0	—	—	—	—
0·19	—	1,830	1,830	—
0·25	1,260	890	1,075	185
0·30	1,050	760	905	145
0·35	870	730	800	70
0·40	700	680	680	20
0·45	610	600	605	5
0·50	590	—	590	—

⅛-In. Diameter Hole.

x	$p-q$
0·6	700
0·5	780
0·4	790
0·3	770
0·2	700
0·1	610
0·0	570
−0·1	—
−0·2	650
−0·3	710
−0·4	740
−0·5	—
−0·6	740

⅛-In. Diameter Hole.

θ	$p-q$	Calculated Value $p = 598$.
deg.		
0	1,830	1,795
15	1,600	1,635
30	1,200	1,195
45	610	600
60	−120	0
75	−450	−440
90	−580	−600

TABLE III.

¼-In. Diameter Hole.

x	$p+q$	$p-q$	p	q
−0·50	530	540	535	− 5
−0·45	535	510	525	13
−0·40	550	580	565	−15
−0·35	600	—	600	—
−0·30	650	630	640	10
−0·25	760	630	700	65
−0·20	930	750	840	90
−0·15	1,240	1,160	1,200	40
−0·14	1,440	1,460	1,050	−10
−0·125	—	1,720	1,720	—
0	—	—	—	—
0·125	—	1,730	1,730	—
+0·14	1,350	1,400	1,375	−25
+0·15	1,160	—	1,160	—
0·20	910	760	885	75
0·25	790	640	715	75
0·30	660	660	660	—
0·35	610	630	620	−15
0·40	560	580	570	−10
0·45	530	600	565	−35
0·50	500	560	580	−30

¼-In. Diameter Hole.

y	$p-q$
0·5	520
0·4	550
0·3	—
0·2	500
0·1	490
0·0	490
−0·1	500
−0·2	510
−0·3	520
−0·4	540
−0·5	520
−0·6	500

¼-In. Diameter Hole.

θ	$p-q$	Calculated Value. $p = 569$
0	1,920	1,710
15	1,530	1,555
30	1,200	1,140
45	580	570
60	− 20	0
75	−400	−420
90	−540	−570

The reverse process of determining r, θ from any point M is difficult. It is therefore necessary to construct a chart from which the values of r can be read off.

This may be carried out in the following way. Draw a series of lines h H, k K, corresponding to given values of r, and mark off on the appropriate axis a corresponding set of values of $R = f(r)$. Also determine a series of

described is too complicated to be reproduced here, but from such a chart curves of constant $\frac{P-Q}{p}$ have been constructed by increments of 0·1 through the whole range of stress. These latter curves are shown in Fig. 9,

$$\tan M\hat{O}y = \frac{OX}{MX} = \frac{2.\widehat{r\theta}}{\widehat{rr} - \widehat{\theta\theta}} = \tan 2\phi$$

showing that the angle which O M makes with the vertical axis is $\pm 2\phi$. The sign is easily chosen for any given point. It is also important to note that from the curves of equal $\frac{P+Q}{p}$ and $\frac{P-Q}{p}$ the curves of equal $\frac{P}{p}$ and $\frac{Q}{p}$ can be readily determined. Thus, for example, if curves of P + Q corresponding to constant values (2 *m*) are known, and a similar set for P − Q corresponding to (2 *n*), then the points of intersection of the series obtained, by giving various values to M and N, correspond to :

$$P = m + n$$
$$Q = m - n$$

as Fig. 12 indicates.

The form of the curves for $\frac{P-Q}{p}$ = a constant, Fig. 9, shows that along a line parallel to the axis of pull, and a finite distance away, the value of $\frac{P-Q}{p}$ reaches a minimum at its intersection with the minimum section, and also passes through a region of higher value as it proceeds outwards.

This confirms the qualitative observations on finite plates. The range of this stress variation may be determined by two independent methods, namely, by photo-elastic measurements of P − Q, or by mechanical measurements of P + Q, since these coincide along a boundary under no applied force. Both forms of measurement are given in Fig. 13*a* in the case of a tension member 0·992 in. by 0·1812 in. in cross-section, to which a load of 100 lb. is applied, giving a mean value of the stress of 556 lb. per square inch at the full section and 1,112 lb. per square inch at the minimum section produced by boring a central hole of $\frac{1}{4}$ in. in diameter. The values of the stresses obtained are also shown by the accompanying measurements, Table I, from which it appears that at a distance from the minimum section corresponding to the half-breadth, the stress reaches a maximum of about 800 lb. per square inch, while at the centre, although the mean average stress is 1,112 lb. per square inch, the actual stress is not more than 600 lb. per square inch, owing to the great concentration of the stress distribution at the inner circular boundary. Although both sets of measurements are not quite identical, and the symmetry is not perfect, their substantial agreement is evident, and taken with the evidence afforded by the disposition of the isochromatic lines they show, very conclusively, that diminution of the section is accompanied by diminution of stress at this point of the minimum cross-section, a somewhat unexpected result, and one not likely to be predicted from general considerations. The stress distribution around the interior contour also varies widely, and in fact has a very large tensional value at the end points of the diameter perpendicular to the line of pull, which gradually diminishes until at an angular distance of somewhat less than 60 deg. it vanishes and changes to compression with a maximum value at the ends of a diameter coincident with the axis.

These values are recorded in Table I, and are also plotted in Fig. 13*b*, together with corresponding values shown by dotted lines for a pull stress corresponding to this width of plate obtained by an approximate calculation. It is worthy of note that the measured values are somewhat less than the values so calculated, although the difference is not large, and tends to diminish with the size of the hole.

The curve of stress distribution across the minimum section is readily obtained by a combination of the methods mentioned above; and as appears from the measurements, Table I, the maximum stress is at the edge of the hole, and almost exactly 3 *p* where *p* is defined as above.

The curve of variations, however, falls somewhat faster than for the case of an infinite plate, as the dotted lines for this case show. The cross stress is, moreover, insignificant, and rises to its maximum value at a radius of about 1·2 *r* to 1·4 *r*, with zero values at each end. The measurements confirm the theory that such stresses are small, and may be neglected except when considerable accuracy is required. If the size of the hole is diminished while the width of the tension member remains the same, the effects produced show the same general characteristics. They have been measured for holes $\frac{3}{4}$ in. and $\frac{1}{2}$ in. diameter respectively, and the values are recorded in the accompanying Tables II and III, and are plotted in Figs. 14*a*, 14*b*, 15*a* and 15*b*.

Along the parallel sides the maximum stresses, already noted, tend to approach to the minimum at the central section, and the inequalities of stress distribution also decrease with the radius of the hole; in fact, with a small hole of $\frac{1}{8}$ in. diameter the difference of stress along the external contours is too small to measure with certainty, and for all practical purposes may be neglected.

On the other hand, the stress variation around the inner contour differs very little from the variations shown to exist in the larger hole, and, moreover, conforms very closely to approximate calculations for the stress distribution. This is apparent in Fig. 15*b* and Table III, where both curves are very close together, but still with measured values of slightly less magnitude than those calculated by the formula. The points of zero stress are, moreover, at angular distances of less than 60 deg. from the diameter perpendicular to the line of pull. With the smaller hole, however, Fig. 15*b*, the two curves practically coincide throughout, and the points of zero stress occur in the positions agreeing with calculations for an infinite width of plate. It may also be observed that the maximum stress is still very approximately 3 *p*.

The cross stresses also show variations which follow the law for $\widehat{rr}$, with maxima which tend towards the position $r = a\sqrt{2}$, as indicated by the theory, as the holes decrease in size relatively to the width of the plate. As their values are obtained by the difference of two sets of measurements, it is not surprising that they do not agree so well with the theoretical expressions as do the values of $\widehat{\theta\theta}$, for any errors of measurement tend in general to accumulate in the values of $\widehat{rr}$ and to become a considerable percentage of the true value.

It is perhaps worthy of note that a practical rule may be derived from the measurements whereby the maximum stress can be determined in terms of the mean stress at the minimum section and the ratio *c* of the width of the plate to the diameter of the perforation. This may be stated in the form :

$$p_{max} = \frac{3c}{c+1} p_{mean}$$

It will be found in general to give fair values unless the hole is relatively large compared with the width of the plate.

It is worth while examining the case of a very large hole in a tension member, because it might possibly be thought that, for such a case, the stress distribution at the minimum section tends to become uniform. It is apparently taken to be approximately so by at least one authority,* but experiment does not confirm this view, as variation in stress distribution at the minimum section is still very great when the diameter of the hole approaches the width of the plate. A case of this kind is shown in the accompanying Fig. 16, in which a hole of 0·88 in. diameter is bored in a plate 1·1 in. wide. The stress distributions recorded there, and in Table IV, show that the relative variation of tension across the section of minimum area is greater than in any of the preceding cases, and when the hole is increased in size still further there is a maximum tension at the inner boundary, which may possibly pass through a zero value as we proceed outwards, and become a compression stress at the outer parallel sides.

TABLE IV.

0·88-In. Hole. Width = 1·1 In.

y = 0 *x* =	*p* − *q*	*x* = 1·1 In. *y* =	*p* − *q*	θ	*p* − *q*
0·44	1,730	0·0	270	0	1,730
0·46	1,440	0·05	300	5	1,600
0·48	1,010	0·10	400	10	1,420
0·50	840	0·20	670	15	1,080
0·52	500	0·30	800	20	720
0·55	270	0·40	800	25	450
		0·50	680	30	220
				36	0
				45	−260
				60	−280
				75	−340
				90	−360

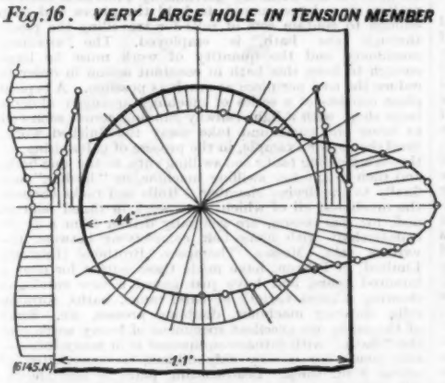
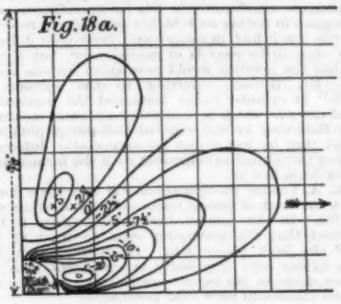
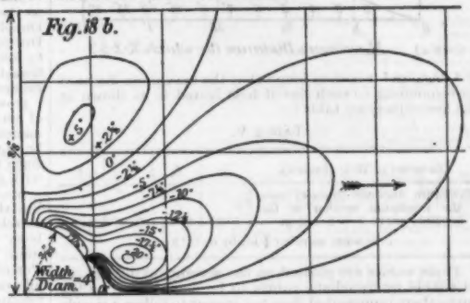


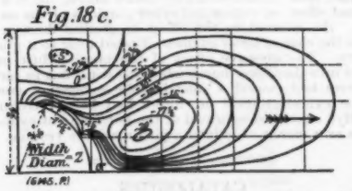
Fig. 16. VERY LARGE HOLE IN TENSION MEMBER

FIG. 17.

OPTICAL DETERMINATION OF ISOCLINIC LINES OF PARALLEL TENSION MEMBERS WITH CIRCULAR HOLES.







* Dr. A. Leon, "Kerbgrösse und Kerbwirkung," Plate 3, Fig. 25. No. 10. Mitteilung aus dem Mechanisch-Technischen Laboratorium der K. K. Technischen Hochschule in Wien.

The great variation in stress at this minimum section is shown in the accompanying reproduction of a colour photograph, Fig. 17, of the region between the circular and straight boundaries.

The danger of fracture at the inner boundary is therefore much increased in such a case if an estimate of the probable maximum stress is derived from average values obtained by dividing the total load by the area of the minimum cross-section, and it is clear that the approximate formula given above is no longer applicable.

In the present example, however, tension is preserved throughout, and it is, moreover, to be observed that the maximum values along the straight boundaries are about three times the value at the central section, and are separated by a considerable interval. Around the periphery of the hole there is now much more tangential compression stress, while the zero value is at an angular distance of about 35 deg.

If such cases are important in practice it might be worth while to consider them in more detail, but it is not possible to make more than a passing reference here, to call attention to the distinctive features observed, and to show their general tendency.

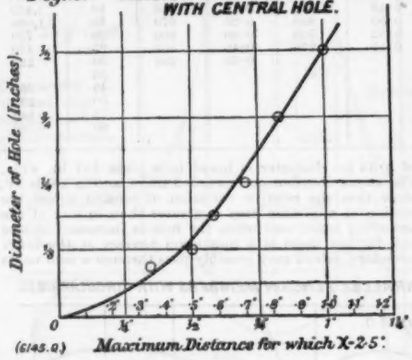
ISOCLINIC LINES.

The isoclinic lines found in the cases cited above also afford some information of value, as may be observed from Figs. 18*a* to 18*d*, of observations made on a tension member $\frac{1}{8}$ in. wide, and with centrally-placed holes having a ratio of width to diameter varying from 8 to 1$\frac{1}{4}$. The principal line $\lambda = 0$ deg. indicates the points where one set of lines of principal stress intersecting $\lambda = 0$ deg. attains a maximum ordinate with reference to the axis, while the other isoclinic lines indicate that there is a gradual movement of the stress lines towards the axis even when the plate approaches an infinite width. This double curvature in the lines of principal stress running more or less axially is shown in earlier papers. Other lines also intersect an isoclinic $\lambda = 0$ deg. at the crown of the hole, and some of these pass around the aperture, but those nearest the centre line terminate abruptly at the contour, as Fig. 7 shows. The point of zero stress around the contour also moves away from the position $\theta = 30$ deg., and its angular distance from the axis increases with the diameter of the hole. The

curves also enable an estimate to be formed of the extent of the disturbance from uniform stress conditions, since it is clear that there must be some finite distance at which non-uniform stress becomes negligible.

Both the isoclinic and isochromatic bands corresponding to this condition are, however, so broad and ill-defined that for accurate work it is necessary to measure the stress distribution over a considerable area, but an approximate distance can be obtained by taking a curve $\lambda = a$ where a is selected arbitrarily provided it is small. The value a in the present examples has been taken as

Fig. 19. TENSION MEMBER ¾ INS. WIDE WITH CENTRAL HOLE.



(G145.Q) *Maximum Distance for which X-2·5.*

2·5 deg., and it is then found that the maximum distance corresponding to each size of hole tested is as shown in the accompanying table :—

TABLE V.

Diameter of Hole (Inches).	⅛	¼	½	¾
Maximum distance (inches) from the minimum section of the isoclinic curve $\lambda = 2{\cdot}5$ deg. ..	0·34	0·58	0·83	1·00

Tension member ¾ in. by 0·1213 in.

These values are plotted on the accompanying Fig. 19 to enable intermediate values to be determined, as the curve there represented does not appear to follow a simple algebraic law.

(To be continued.)

BRITISH INDUSTRIES FAIR, CRYSTAL PALACE, 1920.—The British Industries Fair, organised by the Board of Trade, will be held in the Crystal Palace, London, from the 23rd inst. to March 5. Arrangements have been made to provide interpreters at the Crystal Palace for the use of visitors. No charge will be made for their services. The Department of Overseas Trade will instal a special inquiry office at the fair, and visitors are invited to make application for any information they may require. The department's officers will be prepared to furnish the names of suitable British manufacturers to visitors who may experience difficulty in obtaining the goods they require.

ROYAL AERONAUTICAL SOCIETY NOTICES.—A meeting will take place on Wednesday evening, March 3, at 8 p.m., at the Royal Society of Arts, when Professor Melville Jones, Associate Fellow, will read a paper on "Flying Over Clouds in Relation to Commercial Aviation," Lieutenant-Colonel Tizard, Fellow, presiding. Mr. J. L. Cope's lecture on "Aerial Survey in the Antarctic" will take place at the Central Hall, Westminster, on Wednesday evening, April 7. H.R.H. Prince Albert will take the chair at 8 p.m. The Scottish branch of the society in Glasgow has a membership of about 200. Sections of the Scottish branch are being opened in Edinburgh and Dundee. The chairman is Sir William Beardmore, the offices being situated in Blythswood-square, Glasgow. London members, and particularly students, are reminded that the library of the society, at 7, Albemarle-street, is open on Saturdays from 2 p.m. to 5 p.m.

THE CLOSING OF GERMAN RAILWAY SHOPS.—The German Government has decided to take a step which is likely to cause considerable stir in the country. It is a well known fact, that the conditions in the German railway service are utterly unsatisfactory, one of the troubles being the small amount of work put in hand in the repair shops for rolling-stock. The Government now intends to close 14 of the least satisfactory shops, including those at Berlin, Breslau, Frankfort-on-the Main, and Königsberg. All these shops have worked so badly for a considerable time that they could not possibly pay their way. These works will, however, probably be reopened later if it seems possible to run them on a sound, remunerative basis, but a smaller number of hands will be employed, and those employed will have to sign agreements in which they undertake to work at least 8 hours per day, on piece work pay. The German Railway Minister recently pointed out that, hitherto, so much time has been wasted by the men that unless a material improvement is made in this respect. the day is not far distant when the German railways will be unable to transport the necessary food for the towns.

DIESEL ENGINE USERS' ASSOCIATION.

THERE was a large attendance at the February meeting of the Diesel Engine Users' Association, and a considerable amount of interest was evidenced in the discussion which took place after the reading of Mr. Geoffrey Porter's paper on "Wear of Diesel Engines." The data collected by the author from careful observations and measurements taken over long periods during actual working conditions of Diesel engines, form a useful record, and a very valuable addition to the information previously available on this important subject. The value of Mr. Porter's notes was considerably increased by the tables and plotted curves which accompanied the paper. In dealing with the important question of liner wear, he referred to this as being chiefly influenced by the percentage of ash content in the fuel oil and its variable nature, according to the class of fuel used, the quality and quantity of lubricant, the method of lubrication, the fit of piston and piston rings in the liner, the side thrust due to the connecting rod, and the quality of the material used. The author pointed out the deleterious effect of excessive cylinder lubrication, which resulted in the formation of carbon deposits on the piston. Particulars were given as to the proper clearances in the case of cooled and uncooled pistons of various sizes, and the important subject of "growth" of cast-iron was again referred to. Questions in connection with the wear of pistons, piston rings, air compressor parts, crankshafts, gear wheels, inlet and exhaust valves, fuel valves, cams and rollers and gudgeon pins, were also carefully considered.

Mr. G. W. F. Horner, in discussing the paper, referred to the pleasure which must be felt by manufacturers of Diesel engines in noting such highly satisfactory records. During the war it had, in many cases, been very difficult to keep consecutive records of engine wear, but it was hoped that the practice would now again become more general. Mr. Horner, referring to the subject of "growth" in cylinder liners, instanced the particulars of actual cases in which he had taken accurate measurements. Referring to the wear of fuel-pump plungers, he stated that he had found no appreciable difference since using tar oil fuel as compared with the former wear with petroleum fuel oil.

Mr. W. A. Tookey thought there was very little doubt but that the wear of piston liners and piston rings was correlative. In the case of horizontal engines it had been found that the maximum wear occurred at the joint of the back piston ring. He noticed that Mr. Porter's figures were very fairly in agreement with the allowance made in gas-engine practice in regard to the maximum amount of liner wear permisaible.

Mr. A. N. Rye had not noticed that the use of tar oil fuel had been detrimental to cylinder liners, but it had a marked effect on valves and other portions of the engine gear. He referred to the effect of granite dust in the air in the case of some engines situated near to a granite quarry. The abrasive effect of the granite dust introduced into the power-house when the wind was in certain quarters had caused a considerable amount of trouble in the cylinders until air filters had been introduced. Mr. Rye expressed approval of the barrelling of cylinders liners as a means of reducing piston seizure trouble.

CATALOGUES.

Electric Furnaces.—A catalogue of electrical furnaces in a variety of shapes with control panels and pyrometers, comes from Messrs. A. Gallenkamp and Co., Limited, of 19, Sun-street, London, E.C. 2.

Electric Motors.—A catalogue of direct-current motors, of powers ranging from 0·15 h.p. to 225 h.p. for circuits of 100 volts to 600 volts, comes from the British Thomson-Houston Company, Limited, of Rugby. The explanations are clear, the illustrations sufficient, and the data required by purchasers are stated in the fullest terms; they are given in tabular form for easy reference.

Steel Forgings and Castings.—Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, of Newcastle-on-Tyne, send a catalogue illustrating examples of steel forgings and castings produced at their works, among which examples are included the largest turbine drums, marine straight and cranked shafts, railway axles, &c. Both pressed and hammered forgings are made in very large quantities.

Planing Machine Drive.—A single electric motor drive for a planing machine, with automatic reversing and speeding up over the blank spaces that occur in planing long castings, is illustrated and briefly described in a catalogue issued by the makers, the Metropolitan Vickers Electrical Company, Limited, of Manchester. A direct-current motor, with dynamic braking at the reverse, is employed. The control is simple and all necessary safeguard devices are fitted.

Electric Power in Steel Works.—The production of "bright steel" has made great progress in recent years. The plant required consists mainly of rolling and drawing machines with special hoisting and conveying machinery. The driving power installation is of importance from both efficiency and economy points of view, and, considered as a whole, it presents very exceptional problems. The General Electric Company, Limited, of Queen Victoria-street, London, E.C. 4, undertook the work of equipping the large mills of the Halesowen Steel Company, Limited, near Birmingham, and have issued a special catalogue describing the system which will be of considerable interest and value to engineers. The work was well advanced before the outbreak of the war, and was speeded up and extended to cope with war requirements, so that the output rose from 7,700 tons a year in 1914 to over 27,000 tons in 1918.

Cottage Windows.—A catalogue of steel windows from Messrs. Henry Hope and Sons, Limited, of Smethwick, offers another very substantial proof that engineering firms are anxious to contribute to the solution of the housing question. The firm worked out a series of standard sizes which could be manufactured quickly and cheaply, and then invited 15 prominent architects to design cottages incorporating the standard windows. These designs are reproduced in the catalogue, which is a very handsomely printed book of 40 pages, each 12 in. wide and 18 in. deep. We must forbear comment on the designs beyond saying that they are sufficiently varied to prove that the standard windows offer no obstacle to the architect, in fact, it might not be noticed that the windows are standardised. The windows are made in different sizes and are composed of panes measuring about 9 in. wide and 11 in. deep, and a cheaper variety is shown in which the upright between two panes is omitted. The steel frames are welded at all joints, and all fittings are attached by welding or riveting; no screws or bolts are used. The windows are all arranged to open outwards on vertical pivots—which are of bronze, working in steel. The opening fittings are very substantial and of good appearance.

Galvanising Machinery.—The familiar "zinc" bucket, roofing, tank, &c., involves one of the heaviest of machinery installations for applying the zinc coating to the material, for it is purely a dipping process, though the term "galvanising" has been permanently misapplied to it; the electro-zinc depositing process is much more costly. In the ordinary galvanising process a bath of molten zinc, large enough to hold the pieces and deep enough to contain sets of rolls for travelling the pieces through the bath, is employed. The auxiliary machinery and the quantity of work must be large enough to keep this bath in constant action in order to reduce the cost per piece as much as possible. A typical plant consists of a series of machines arranged along a large shop, with a light railway running across each end to bring the parts and take away the finished work. Steel sheets, for example, in the process of galvanising, go through pickling tanks and swilling vats, to the zinc bath, and then to another swilling machine, or "bosher," and finally to the drying chamber. Rolls and racks connect the machines, all of which must work in timed relation and, for this reason, are generally driven from a single countershaft with chain-belt connections between the various sets. Messrs. Thompson Brothers (Bilston), Limited, of Bilston, have made these outfits for over a hundred years, and have just issued a new catalogue showing a great variety of vats, tanks, baths, forming rolls, shearing machines, doubling presses, &c. Some of the tanks are excellent specimens of heavy work, and the "bath" with furnace equipment is in many forms—one, made for use by shipbuilders, is constructed of plates 2 in. thick. Lead-coating plant is also shown. All such plants are made to order, and it is usual to supply specially-skilled practical men to work them.

THE INSTITUTE OF METALS.—The annual general meeting of this Institute will be held in the building of the Institution of Mechanical Engineers, on Thursday and Friday, March 11 and 12; on Thursday from 4 p.m. to 6 p.m., and from 8 p.m. to 10 p.m., and on Friday from 10.30 a.m. to 1 p.m. and from 2.30 p.m. to 4.30 p.m. The following communications are expected to be submitted: (1) Fifth Report to the Corrosion Research Committee, by Mr. G. D. Bengough, M.A., D.Sc., Member, Mr. R. M. Jones, M.Sc., and Ruth Pirret, B.Sc. (London); (2) "The Action on Aluminium of Hard Industrial Waters," by Mr. Richard Seligman, Ph.Nat.D., Member, and Mr. Percy Williams, B.Sc., Member (London); (3) "The Art of Casting in High Tensile Brass," by Mr. J. Neil MacLean (Glasgow); (4) "The Removal of Internal Stress in 70:30 Brass by Low Temperature Annealing," by Mr. H. Moore, O.B.E., B.Sc., F.I.C., and Mr. S. Beckinsale, B.Sc., A.I.C. (Woolwich); (5) "Zinc Alloys with Aluminium and Copper," by Mr. W. Rosenhain, B.A., D.Sc., F.R.S., Vice-President, Mr. J. L. Haughton, M.Sc., Member, and Kathleen Bingham, B.Sc., Member (Teddington); (6) "A Model for Representing the Constitution of Ternary Alloys," by Mr. W. Rosenhain, B.A., D.Sc., F.R.S., Vice-President (Teddington); (7) "Tin-Phosphorus Alloys," by Mr. A. C. Vivian, B.A., A.R.S.M., Member (London); (8) "Some Notes on the Effect of Hydrogen on Copper," by Mr. W. C. Hothersall, M.Sc.Tech., and Mr. E. L. Rhead, M.Sc.,Tech., Member (Manchester); (9) "The Effect of Progressive Drawing upon some Physical Properties of Commercially Pure Copper," by Mr. W. E. Alkins, M.Sc., Student Member (Manchester); (10) "The Influence of Cold Rolling on the Physical Properties of Copper" by Mr. F. Johnson, M.Sc., Member (Birmingham); (11) "The Study of Thermal Electro-Motive Force as an Aid to the Investigation of the Constitution of Alloy Systems," by Mr. J. L. Haughton, M.Sc., Member (Teddington); (12) Note on "The Polishing and Etching of Zinc for Micro-Examination," by Mr. H. H. Hayes, Member (Birmingham); (13) "Idiomorphic Crystals of Electro-Deposited Copper," by Mr. W. E. Hughes, B.A., Member (London). The annual dinner will be held at the Criterion Restaurant, Piccadilly Circus, W. 1, on Friday, March 12, at 7.45 p.m. for 8 p.m., under the chairmanship of Engineer Vice-Admiral Sir George Goodwin, K.C.B., LL.D. The next gathering of members will take place on June 10 (not on May 5 as previously announced), when Professor Carl A. F. Benedicks, Ph.D., Stockholm, Sweden, will deliver the tenth May lecture, his subject being "Recent Progress in Thermo-Electricity." The place and time of the lecture will be announced later. The annual autumn meeting will be held in September, 1920. A further announcement as to this will be made in due course.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Name, &c., of the Communicators are given in italics.

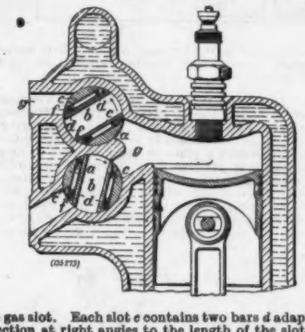
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

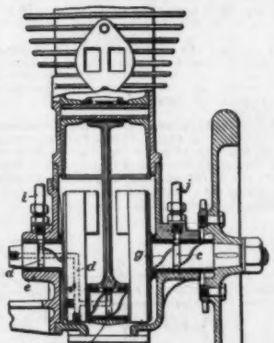
GAS ENGINES, PRODUCERS, HOLDERS, &c.

135,273. [C. J. Murfitt, Palmer's Green, London. Internal-Combustion Engines. (4 *Figs.*) November 18, 1918.—The invention relates to an oscillating or rotating valve for an internal-combustion engine, in which passage of gases around the valve is more or less prevented by rollers contained in the wall of the valve parallel to the axis and pressed against the inner face of the valve casing by springs. The cylindrical valve *a* has a slot *b* for passage of gas, and a slot *c* on each side



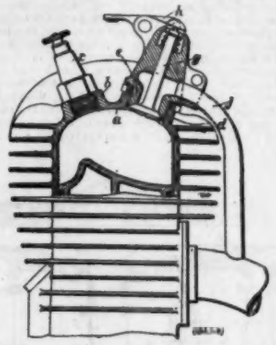
of this gas slot. Each slot *c* contains two bars *d* adapted to slide in direction at right angles to the length of the slot and urged apart by springs of piston ring steel. The outer face of each bar forms a seating for a roller *f* contained in the slot, and suitably prevented from leaving it, such as by being longer than the valve ports *g* of the cylindrical valve casing. Piston rings prevent passage of gas between the valve and its casing in direction parallel to the axis. (*Accepted December* 3, 1919.)

135,309. R. S. Whaley, Edgbaston, Birmingham. Internal-Combustion Engines. (1 *Fig.*) November 23, 1918.—This invention relates to lubricating provision for an internal-combustion engine, of the type in which lubricant is adapted to be applied through the crank to the big-end of the connecting rod. An annular circumferential groove *a*, *b*, *c*, is provided in each bearing part of the crankshaft, and in the crank-pin. A conduit *d* extends from the annular groove in the crank-pin, within the interior of the crank-pin, crank-arm and crankshaft, to the annular groove occurring in the bearing



part of the crankshaft on one side of the crank-pin. *i* is a conduit for supplying lubricant to the groove *c* through a perforation in the bearing boss *e*. To the annular groove *c* in the bearing part of the crankshaft occurring on the other side of the crank-pin, lubricant is independently delivered by a conduit *j*. Helical or other grooves *g* are provided in the bearing parts of the crankshaft, these grooves being in communication with the circumferential grooves aforementioned. Perforations are provided in the big end of the connecting rod to permit of the collecting of any further lubricant from the crank-pin in the interior of the crank-casing. (*Accepted December* 3. 1919.)

135,310. R. S. Whaley, Edgbaston, Birmingham. Cylinder Heads. (1 *Fig.*) November 23, 1918.—*a* represents the cylinder head, the curvature being at a large radius over the main area, and being of a small radius near to the cylinder wall. The domed cylinder head is furnished with a boss *b* adapted to receive a sparking plug *c*. The axis of this boss *b* is located radially to the axis of the major curve of the internal surface of the cylinder head occurring at the section containing said axis, and the sparking plug is located out of the centre or axis of the cylinder and conveniently symmetrically with the relief valve now to be described. *d* is another boss provided in the cylinder head and internally threaded to accommodate a relief valve housing *e* carrying a valve for relieving the pressure when starting, which valve may be of the mushroom type, the head of the valve being arranged to occur at or substantially at the internal surface of the cylinder head, and the stem *g* of the valve being adapted to extend outwardly radially of the axis of the curve of major radius of the internal surface of the cylinder head. Outwardly



this stem *g* is adapted to be operated through the medium of a lever *h* from any suitable provision, said lever *h* being pivotally carried by the housing *e* against the resistance of a spring pocketed within an appropriate part of the housing *e*. The housing *e* is adapted to receive the extremity of a delivery conduit *j*. The piston head is also curved as illustrated to appropriately direct the flow of gases in the scavenging process. (*Accepted December* 3, 1919.)

MINING, METALLURGY AND METAL WORKING.

135,237. The Morgan Crucible Company, Limited, Battersea, London, and C. W. Speirs, Battersea, London. Electrically-Heated Furnaces. (5 *Figs.*) October 12, 1918.—This invention relates to means for regulating or controlling the current supplied to electrically-heated crucibles, retorts, muffles and melting furnaces of the "resistor" type, wherein the heat is generated in the container itself, or in a resistance surrounding the container, and wherein the electrical connections are generally made by means of water-cooled terminals. According to this invention, the very finest degree of regulation of temperature is effected by making the extension pieces cylindrical, or of circular section, and constructing the water-cooled metal

Fig. 1.

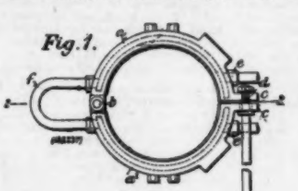
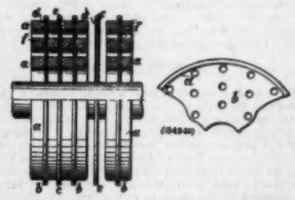


Fig. 2.

terminals, which embrace the said extension pieces or electrodes, each in two parts connected by screws or other mechanical devices whereby the grip of the said terminals on the extension pieces or electrodes may be varied. The water-cooled terminal is in the form of a ring made in two sections *a*, *a1*, hinged together at *b* and provided with lugs *c*, *c*, through which a pressure-regulating screw *d* is passed so that by rotating the screw by means of a hand wheel, the two members of the terminal can be clamped together on to the extension piece. *e*, *e*, are nozzles for the attachment of the circulating pipes; *f* is a tube connecting the two sections together so that a continuous circulation may take place. (*Accepted December* 3, 1919.)

RAILWAYS AND TRAMWAYS.

134,940. C. W. C. Hine, Dorking. Buffer Springs. (3 *Figs.*) November 15, 1918.—This invention relates to buffer springs of the kind comprising two or more india-rubber rings arranged concentrically one within the other, and to which is moulded a metal plate formed with perforations through which extend india-rubber fillings that connect the india-rubber rings at opposite sides of the plate together and maintain the india-rubber rings at the desired distance apart. The spring shown comprises



three spring elements, each consisting of three concentric india-rubber rings *a* located at each side of a metal plate *b*, that is moulded into them and maintains them the desired distance apart. As usual, the metal plates *b* are formed with holes through which extend india-rubber fillings *f* that connect together the india-rubber rings at opposite sides of the plates. Metal dividing plates *c*, not connected to the interposed indea-rubber rings, are located between the spring elements as shown. For the sake of clearness the spring element and the corresponding dividing plate *c* at the right-hand sides of the figures are shown separated from each other and from the other spring elements of the spring column. The metal plates *b* are each formed with a marginal shoulder *d*, Figs. 1 and 2, say one thirty-second of an inch or so in depth, to prevent outward movement of the outer india-rubber ring relatively to the plate. (*Accepted November* 26, 1919.)

STEAM ENGINES, PRODUCERS, HOLDERS, &c.

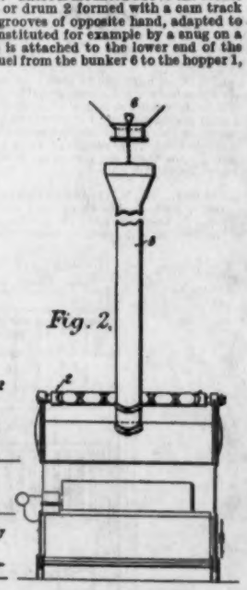
135,226. W. J. Thompson, Wolverhampton, and V. Smith, Wolverhampton. Water-tube Boilers. (4 *Figs.*). August 21, 1918.—This invention relates to water-tube boilers of the type in which water tubes communicate between drums which lie in directions transverse to the tubes, and in which the drums are formed with prepared formations, which run in a direction transverse to the direction of the drums, for the purpose of providing plain or flat surfaces at right angles to lengths of water tubes of which the ends pass through holes which are formed through such surfaces. Each set of prepared formations *a*, *b*, which runs in a direction transverse to the direction of a

drum, is of a width, in a direction lengthwise of the drum, which allows it to receive tubes of two or more transverse sets of tubes, and each plain or flat surface of a prepared formation is formed preferably, to receive two or more ends of tubes of each set of a pair of sets, or of all of a group of sets, and, according to the distinctive feature of this invention, the drum is originally made cylindrical and is maintained cylindrical at all the portions thereof which lie between the transverse sets of prepared formations for receiving the tube ends, thus ensuring that such portions of the drum will be of maximum strength. (*Accepted December* 3, 1919.)

135,314. Babcock and Wilcox, Limited, London, H. H. Baker, Monkseaton, and C. S. Davy, Dulwich. Stokers. (2 *Figs.*) November 27, 1918.—The invention consists broadly in the provision of means whereby the lower end of a chute leading to the stoker is automatically caused to travel continuously back and forth transversely of the direction in which the fuel is fed by the stoker. There is mounted above the stoker hopper 1 a rotary cylinder or drum 2 formed with a cam track constituted by two helical grooves of opposite hand, adapted to be entered by a follower constituted for example by a snug on a nut-forming element which is attached to the lower end of the hanging chute 5 supplying fuel from the bunker 6 to the hopper 1,

Fig. 1.

Fig. 2.



and which in the rotation of the cylinder or drum 2 is caused to reciprocate axially thereof. The cylinder or drum 2 may be driven by chain gearing from a revolving shaft, such as the sprocket shaft at the front of the stoker if of the chain-grate type, or from a separate shaft. In the embodiment shown, the cylinder or drum 2 is driven from the shaft 7. It will be evident that as the cylinder or drum 2 rotates the lower end of the chute 5 will travel across the stoker hopper 1 and, upon reaching the end of its travel in one direction, will travel the same distance in the opposite direction, the reciprocating movement being continuous, so that the dust and larger pieces of fuel discharged from the chute will be well distributed in the stoker hopper. (*Accepted December* 3, 1919.)

134,067. The Hon. Sir C. A. Parsons, Newcastle-on-Tyne, S. S. Cook, Newcastle-on-Tyne, and L. M. Douglas, Newcastle-on-Tyne. Packing. (5 *Figs.*) November 13, 1918.—This invention relates to glands for packing rotating shafts of the type consisting of a ring divided radially into a number of arc-shaped portions which bear independently on the shaft. The invention consists in divided packing rings for rotating shafts provided on the internal periphery with a circumferential groove placed in communication with steam on the high-pressure side of the ring. The invention also consists in providing in the packing rings radial ducts to admit high-pressure steam to the internal circumferential groove. The invention further consists in providing longitudinal grooves in the internal periphery of the ring to admit high-pressure steam to the internal circumferential groove. 1 are gland rings of rectangular cross-section and divided in the well-known manner into segments which are held together and in contact with the shaft by a helical garter

spring 2 and also by high-pressure steam admitted to the external peripheries of the rings. A circumferential groove 3 is formed in the internal periphery of each ring, being preferably placed as indicated to one side of the centre line of the ring toward the

Fig. 1.

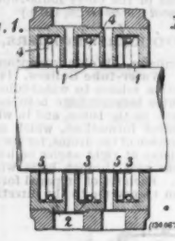
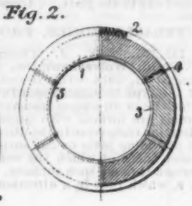
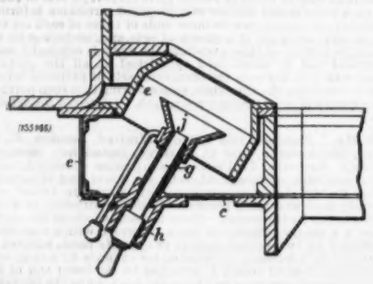


Fig. 2.



high pressure, which is assumed to be acting from the left. High pressure steam is admitted to the grooves 3 either by means of radial ducts 4 or by longitudinal grooves 5 cut in the internal surface of the rings, or as indicated both means may be employed. (*Sealed.*)

135,145. H. A. Thompson, North Shields, C. Zulver, London, and E. Smith, South Shields. Furnace Fronts. (1 *Fig.*) June 23, 1919.—This invention relates to liquid fuel fitting for furnace fronts to enable a furnace provided therewith to be fed with either solid or liquid fuel, or both, simultaneously. According to this invention, the liquid fuel burner *g* is supported in a holder *h* lodged in an aperture in the front wall of the casing *c*, and the said burner extends across the casing into an air cone *e*



lodged in an aperture in the front plate *a* of the furnace. This air cone is in open communication at one end with the space within the casing *c*, and at the other end with the furnace space. An air regulator cone *j* is provided on the burner within the air cone, and this regulator cone may be arranged so that its position can be adjusted, by means of a rod *k* accessible from outside the casing *c*, or the cone *j* may be fixed to the burner. (*Accepted November* 26, 1919.)

135,004. W. N. Haden, Trowbridge, C. I. Haden, Trowbridge, and F. H. Horton, London. Steam Generator. (2 *Figs.*) December 12, 1918.—This invention relates to boilers of the type in which sets of water tubes inclined upwardly in the

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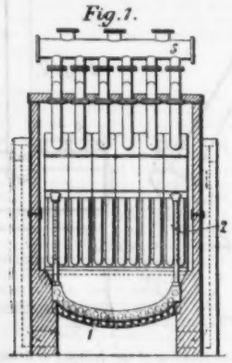
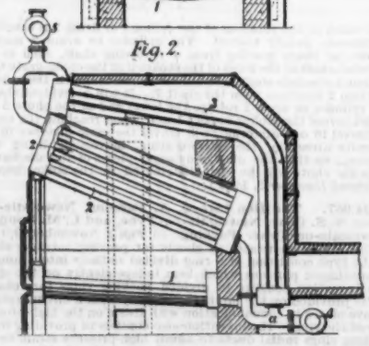
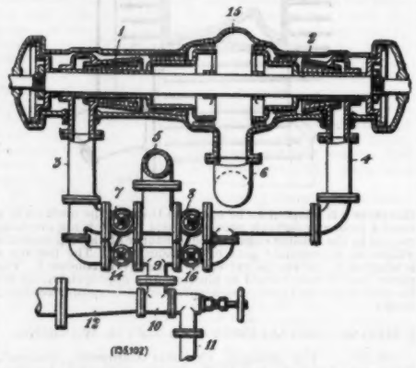


Fig. 2.



same direction are connected with headers at each end, to which headers the flow and return service pipes are connected. The tubes 1 form the furnace bars, the tubes 2 are arranged in the furnace and the tubes 3 in the combustion chamber or down-take from the furnace. Each of these sets is supplied from a connection *a* on the return pipe 4 and lead to the flow pipe or outlet header 5. The inclination of the pipes throughout is in an upward direction, thus facilitating the passage of the water and preventing a deposit at any point likely to be injurious to the flow. (*Accepted November* 26, 1919.)

135,102. F. Ljungstrom, Lidingon, Sweden. Turbines. (2 *Figs.*) March 21, 1919.—This invention relates to means for cooling idle-running turbines. The invention consists in an arrangement so devised that air, live steam or exhaust steam from a power-delivering turbine will be sucked through an idle-running turbine in a direction opposite to the normal direction of flow of the steam, so that this air or steam, in absorbing heat from the inner parts of the idle-running turbine, will be heated to a degree which in some cases may even correspond to the fall of temperature to which the steam is subjected in the power-delivering turbine. 1 indicates the main turbine adapted for forward running, and 2 the reverse turbine, which is somewhat smaller. 3 and 4 are the steam supply pipes for the corresponding turbines 1 and 2, said pipes being coupled to the main supply 5 through the inlet valves 7 and 8 respectively. 6 is the common



exhaust pipe. The valves 7 and 8 are so constructed and connected to other valves 14 and 16, respectively, that when either of the former is closed, and thus the connection between 3 and 5 or 4 is closed, the valve 14 or 16 respectively will be opened, so that connection is automatically established between the pipe 3 and the T-tube 9, or the pipe 4 and said T-tube 9. This T-tube 9 is connected with an ejector 10 provided with the water supply 11 and the exhaust pipe 12, 13 being a hand wheel for a valve adapted to regulate the water supply. If the turbine system rotates for instance in the working direction of the turbine 1, the valves 7 and 8 are so adjusted as to provide communication between the tubes 5 and 3 on one hand, and between the tubes 4 and 9 on the other hand, in which case the turbine 2 rotates backwardly and the exhaust steam from the turbine 1 is then sucked by the ejector 10 from the space 15, through the turbine 2, tube 4, valve 16 and tube 9. *Accepted November* 26, 1919.)

135,583. South Metropolitan Gas Company, London, and A. Kirby, East Greenwich, London. Liquid Fuel Burners. (3 *Figs.*) November 26, 1918.—According to this invention, the burner consists of a steam jacketed pitch chamber *a* having a nozzle into which enters a needle *j* for regulating the delivery of the pitch. The nozzle extends into a pipe *l*, and surrounding the nozzle is a steam chamber *m* from which extends two passages, one *n*, between the inner end of the pipe and the

Fig. 1.

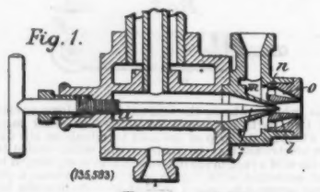
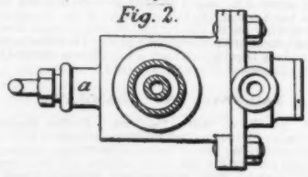


Fig. 2.



nozzle, and the other *o*, to the outer end of the pipe. Upon the inner end of the nozzle is a collar which fits into a circular recess in the walls of the steam jacket, from which walls extend flanges *p* which are bolted to corresponding flanges *q* on the walls of the steam chamber surrounding the nozzle. This construction allows of easy removal of the nozzle and steam chamber, whereby easy access may be obtained to the pitch-chamber for cleaning purposes. (*Accepted December* 10, 1919.)

MISCELLANEOUS.

135,271. A. J. Instone, Crouch End, London. Ice-making Machinery. (2 *Figs.*) November 18, 1918.—This invention relates to ice-making machinery. According to this invention, an ice-making machine comprises a casing *a* divided into spaces tapering upwards by hollow partitions *c* and having a removable bottom cover *d* to allow of the removal of the blocks of ice. The bottom cover is preferably lowered, and then tilted in order that the blocks may be delivered at one end. A false bottom *k* may be secured to the bottom cover, and an air delivery pipe *l* passes between the false bottom and the bottom cover, and air is blown into the spaces through nozzles on the pipe. When the bottom cover is lowered these nozzles are easily thawed and cleaned. The freezing medium is fed to the hollow partitions *c* through a pipe near the bottom of the casing and passes away through a pipe near the top. Ammonia may be used as the freezing medium, in which case it is fed in a liquid form through the pipe near the bottom and passes away as a vapour through the pipe near the top. In order to loosen the ice from the moulds, the vaporised ammonia mentioned above is pumped into the hollow partitions, causing the vapour to become liquid, but by lowering the pressure the liquid ammonia can be again vaporised and used for cooling the moulds in this or another machine.

Fig. 1.

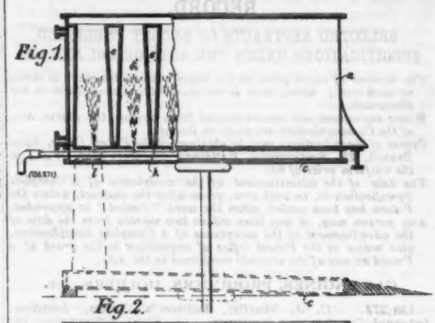


Fig. 2.

When brine is used as the freezing medium, it is necessary to heat it before using it for thawing out the ice. (*Accepted December* 3, 1919.)

135,333. Thos. and Wm. Smith, Limited, Newcastle-on-Tyne, and S. Pile, Newcastle-on-Tyne. Rope-making Machinery. (2 *Figs.*) December 7, 1918.—According to this invention, each rope or strand is so led that it comes into contact with or passes through a plate or block capable of movement, but normally held in position by a spring. The movement of any of the blocks against the action of its spring actuates a switch which causes the stoppage of the machine. On the central spindle *a* of the closing machine between the reels *b* and the closing dies *c*, is bolted a ring *d* carrying cylinders *e*, in each of which is a block *f* capable of radial movement and pierced with a hole *g*;

Fig. 2.

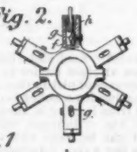
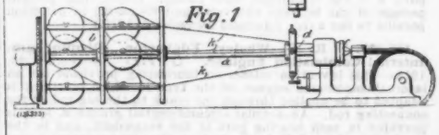


Fig. 1



a spring *h* normally holds the block in the inner end of the cylinder. Tappets are carried by the blocks. The walls of the cylinders are slotted to allow the strands *k* to be threaded through the sides of the cylinders and through the holes *g* in the blocks. Each block is grooved so that it may be prevented from turning by a set screw. During normal running of the machine the blocks remain in their inmost positions, but should the tension of any one of the strands owing to difficulty in reeling be increased the strand will cause its block to move outwards so that its tappet projects further from the cylinder and is brought against a switch lever *m*, whereby the machine is stopped. (*Accepted December* 3, 1919.)

133,414. J. Harkness, Gretna. Concrete Buildings. (5 *Figs.*) October 4, 1918.—This invention relates to the construction of buildings of concrete. The building wall is formed of upright beams 1 of concrete of H-section, set on a suitably-cast base 2, with the flanges abutting and having a tongue and groove or other fitting with one another as indicated at 3, the webs of said upright beams constituting studs at 4. The upright

Fig. 1.

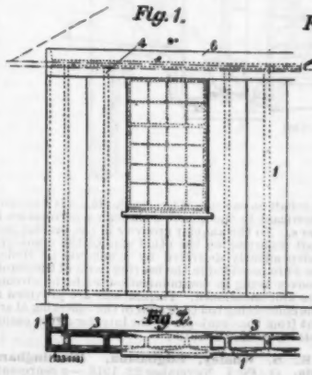
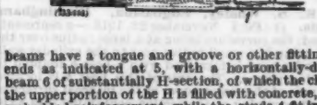


Fig. 3.

Fig. 2.



beams have a tongue and groove or other fitting at their upper ends as indicated at 5, with a horizontally-disposed concrete beam 6 of substantially H-section, of which the channel 7, forming the upper portion of the H is filled with concrete, in which may be embedded reinforcement, while the studs 4 fit into the channel 8 formed by the lower portion of the horizontal H-beam. (*Sealed.*)